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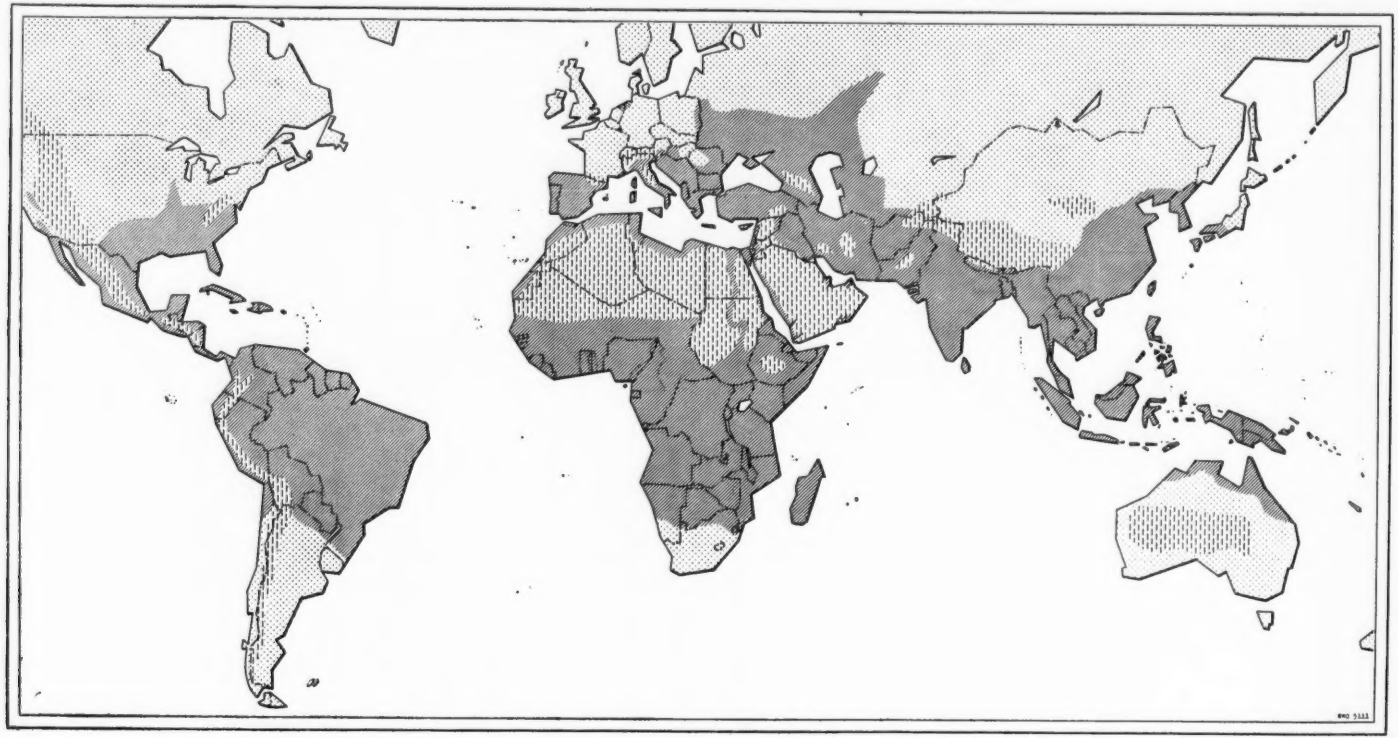
FIG. 1. GEOGRAPHICAL DISTRIBUTION OF MALARIA BEFORE 1946 (BEFORE RESIDUAL INSECTICIDES WERE USED)



Territories free of malaria

Territories where malaria transmission is precluded because of altitude or desert conditions

Malarious territories

NATURE AND EXTENT OF THE PROBLEM*

HISTORY

The usual clinical signs and symptoms of plasmodial infections are so characteristic that when they are specified, whether in ancient, mediaeval, or modern writing, one safely assumes that the illness thus described must have been malarial, regardless of names applied to it at various times and places. Because references to these intermittent fevers can be found in the literature of all historical periods, it is generally agreed that malaria has been present from earliest times.

Malaria was never, and is not today, evenly distributed throughout the world. There is no evidence in the records available, for example, that it was common in Egypt from the time of Imhotep and the Old Kingdom, about 3000 B.C., to about the seventeenth century before Christ; yet the disease was undoubtedly widespread in earliest times in the regions that embraced Babylonia and Assyria, and India and south China. It has continued to be troublesome in the latter areas up to the present day.

To what extent malaria afflicted the Cretan civilization before 1500 B.C. is not clear, but intermittent fevers were subsequently well known in ancient Greece. The Hippocratic writings described the periodicity of malaria paroxysms and noticed that the disease was most prevalent in marshy areas. The intermittents became more common in Greece after 400 B.C.; and some authorities believe that they constituted an important factor in the decline of physical vigour, intellectual power, and moral fibre which resulted in the downfall of Greece from its high place of world leadership. Greek medical writers in Alexandria and Rome until the third century after Christ continued to give good descriptions of the intermittent fevers. By that time these fevers had apparently begun to appear also in the delta of the Nile, but never to any great extent.

There is no evidence that malaria was common among the ancient Etruscans of Italy, but the disease certainly was prevalent during the Roman Republic and Empire. It became so disturbing in the Roman Campagna, and even in Rome itself, that a goddess of tertian and quartan fevers, the " Dea Febris ", was worshipped for preventive and curative help. Certain Roman observers, such as Varro and Columella, clearly noted an association between marshes and malaria. Some authorities believe that, as in Greece, so in Rome, malaria was a powerful factor in accelerating the decline of a civilization.

During the Middle Ages, intermittent fevers were widespread throughout much of Europe and Asia and doubtless also of Africa. But there is a question as to whether or not they occurred at all in the Americas up to the time when Columbus established a colony at Isabella, on the north shore of Hispaniola, in 1493. Many historians believe that the gametocytes of the plasmodia were carried to the Americas by these colonists. Other equally qualified historians, such as Arcos of Ecuador and Jaramillo-Arango of Colombia, suggest that malaria may have been taken to the Americas in the dim past when Asians migrated to the western coasts. Arcos states that malaria was rampant, for example, among the armies of Pachacutec in 1378. Whatever the truth may be, malaria was well

* This special number of the *Chronicle* was prepared by Dr. E. J. Pampana, Chief, Malaria Section, WHO, and Dr. P. F. Russell, Rockefeller Foundation, Special WHO Malaria Consultant. Dr. Russell prepared the sections " Nature and extent of the problem ", " Methods of control ", " Present obstacles ", and " Implications of malaria eradication "; and Dr. Pampana, the remaining sections.

known in the Americas from the sixteenth century onwards, extending at times all the way from northern Argentina and Chile to southern Canada.

During the Renaissance of the fifteenth and sixteenth centuries, there were no great advances in knowledge of malaria. In the seventeenth century, cinchona bark began to be used in treating malarial fevers. This made possible a much clearer definition of the malarial fevers, which was further sharpened by the considerable attention Sydenham gave them during severe epidemics in England in 1661-64. Also in this century, the belief became widespread that the intermittent fevers were caused by bad air, particularly from marshy places.

The eighteenth century saw the beginnings of modern hygiene; but malariology was not ready to reap much benefit from this awakening; and the disease continued to be widespread, in endemic and epidemic forms. The nineteenth century was one of fundamental progress: the etiology of the disease was uncovered, including the identity of the pathogen and mode of its transmission.

The name of the disease originated in Italy, where " mala ", meaning bad, and " aria ", meaning air, were joined to form the word " malaria ", referring at first to the cause, not to the disease. This gave rise to the term " malarial fevers ". Finally, from about 1900, the word " malaria " assumed its present usage in English, denominating the disease, not its cause.

PREVALENCE AND DISTRIBUTION

Data do not exist that permit an accurate estimate of the total number of malaria cases occurring in the world each year. But, on the basis of acquaintance with malarious areas and wide reading of pertinent reports, one might estimate that, among the approximately 2.5 billion persons on the earth, more than 250 million have clinical attacks of malaria, and possibly 2.5 million die of the disease each year. Better estimates would, of course, be possible if more information were available from the USSR and south China.

Since 1920, malaria has been reported as far north as the Dvina River, near Archangel, in the USSR (64°N), and as far south as Córdoba, in Argentina (32°S). It has occurred as high as 2770 m (9086 ft) in the Cochabamba region of Bolivia, where *A. pseudopunctipennis* is the vector, and at 2591 m (8500 ft) near Londiani, in Kenya, Africa, where imported *A. gambiae* and *funestus* shelter in native huts. In Tadzhik SSR, in south Central Asia, it is said that *A. superpictus* is a malaria vector at 2850 m (9348 ft). By way of contrast, the disease has also been known in the Dead Sea basin, 400 m (1312 ft) below sea level. Of course, within these limits of altitude and latitude, many areas are not infested.

In the central and south Pacific region, such islands as the Galapagos, Marquesas, Fiji, New Caledonia, New Zealand, Marshalls, and Carolines are entirely without *Anopheles* and so are not malarious. The Hawaiian Islands are also free of malaria. On Guam, *Anopheles subpictus indefinitus* appeared after the beginning of the Second World War, but up to the present time malaria transmission has not taken place.

Very likely, malaria reached its maximum world dissemination between 1855, when it was found in southern Canada, and 1922-23, when it touched the Arctic Circle in Russia. Since the latter date, there has been a downward trend in both distribution and prevalence, considerably more marked in some countries than others and recently much accelerated by residual spraying with insecticides. For instance, in formerly malarious parts of Brazil, British and French Guiana, Cyprus, Greece, Italy, Mauritius, Venezuela, the USA, and Yugoslavia, there has been a tremendous decline in malaria

morbidity and mortality. Malaria no longer occurs in Chile and seldom in Argentina. In wide areas of Bombay and Mysore States in India, and throughout Ceylon, transmission has been almost completely interrupted by modern control; and many other malarious countries can now point with pride to areas in which the disease no longer constitutes a public health problem. However, intense malaria is still found in certain parts of the Americas between 15°N and 15°S, in Asia south of 40°N, in Indonesia, in the south-west Pacific, and in Africa (see fig. 6, page 44).

SOCIAL AND ECONOMIC CONSEQUENCES

Malaria is a chronic, invalid-producing disease which does not directly kill a high percentage of its victims, although it is often a major cause of infant mortality. The disease results in an increased number of deaths from other causes and lowers life expectancy; but, except in epidemic times, it is insidious rather than dramatic in its effects. Nevertheless, over the centuries, malaria has had a profound influence on thousands of communities throughout the world. Whether or not, as some historians assert, it was decisive in the downfall of Greece and Rome and in the mysterious depopulations that left massive ruins in Polonnaruwa, Ceylon, and Angkor-Wat, Cambodia, cannot be determined; but there is ample testimony to the fact that malaria has been one of the great scourges of humanity because of its stunting of physical and mental development, its notorious restricting of social growth, and its blighting of agriculture, commerce, and industry.

Christophers,[1] a most careful observer, wrote in 1926 :

> " Whether from the point of view of enhanced mortality, sickness and individual suffering, or from the effect of preventing natural increase and sapping the vitality of populations, or the paralysing effect on industry and exploitation of the mineral or other natural wealth of the country, or in the direct loss to Government in a variety of ways, malaria is universally recognised as the most important sanitary problem with which India has to cope."

Sinton,[2] another keen student of malaria, stated in 1936, also with regard to the disease in India :

> " The problem of existence in very many parts of India is the problem of malaria. There is no aspect of life in this country which is not affected, either directly or indirectly, by this disease. It constitutes one of the most important causes of economic misfortune, engendering poverty, diminishing the quantity and the quality of the food supply, lowering the physical and intellectual standard of the nation, and hampering increased prosperity and economic progress in every way."

Many other quotations could be given. For example, Sigerist, the medical historian, discussing malaria in the Roman Campagna, commented that " the entire history of a landscape was determined by a single disease ".

Effect on birth-rate

Malaria affects a country's birth-rate both by limiting the number of conceptions and by causing abortions and still births. This is understandable in view of the predilection of malaria parasites for destroying red blood cells and for congregating in large numbers in the placenta. Giglioli[3] reported that in British Guiana malaria reduced fertility and depressed the birth-rate : the latter, in the presence of malaria control, rose from 35.6 in 1946 to 44.3 in 1952. In Mauritius, the birth-rate went from 38.4 in 1946 to 48.1 in 1952, and in Venezuela from 37.6 in 1946 to 43.7 in 1952, in each case during a country-wide malaria eradication project.

[1] Christophers, S. R. (1926) *Rep. Med. Res. Workers Conf. for 1925*, pp. 30-38. Quoted by Sinton, J. A. (1935) *Rec. Malar. Surv. India*, **5**, 225

[2] Sinton, J. A. (1936) *Rec. Malar. Surv. India*, **6**, 159

[3] Giglioli, G. (1948) *Malaria, filariasis, and yellow fever in British Guiana*, Georgetown, p. 65

Sometimes, however, malaria control is not accompanied by an increased birth-rate; in fact, the number of births may decline. For example, the change in Ceylon during a period of firm malaria control has been negligible—from 38.4 in 1946 to 39.5 in 1952. In Sardinia the rate of 26.9 in 1946 fell to 24.8 in 1952; and in Cyprus the 1946 rate of 32.4 dropped to 26.8 in 1952.

Effect on death-rate

Malaria affects the death-rate directly by killing about 1%, on the average, of those who have clinical attacks, and indirectly by lowering the resistance of the other 99%. In times of epidemics, large numbers may die of malaria. For example, in Mauritius in 1867, a malaria epidemic resulted in 6000 deaths in a single month in Port Louis, which had a total population of only 47 000. In the Punjab in October and November 1898, during an epidemic of malaria, there were recorded more than 307 000 deaths, as compared with a normal average of 50 000 per month. The Ceylon epidemic of 1934-35 destroyed 80 000 lives in seven months' time. When *A. gambiae* invaded Brazil, it caused an epidemic that in six months of 1938 produced over 100 000 cases of malaria, with more than 14 000 deaths. Other instances could be cited, but these are exceptions rather than the rule. For the most part, malaria has quietly but consistently lowered the vitality of a community without causing sufficient alarm to stimulate effective control.

Numerous observers have reported that an increased incidence in malaria is followed by a general increase in morbidity and mortality from other causes; and the more widespread malaria is, the greater the effect. When the rate of malaria prevalence falls, if the disease has been common, the general morbidity- and mortality-rates will concurrently decline.

The direct and indirect effects of malaria are more marked among infant and child populations. Infant mortality in India, for instance, has long been known to be about twice as high in malarious districts as in relatively healthy areas. Bruce-Chwatt [4] reports malaria mortality-rates per 1000 in Nigeria as 12.5 in infants, 7.0 in small children, and 0.5 or less in older children and adults. Following malaria control in Mauritius, infant mortality dropped from an average of 150, in the period 1934-48, to 80.8 in 1952; and, in Venezuela, the number decreased from 110 to 80 in four years of malaria control.

The three main causes of infant mortality are generally congenital and developmental defects, alimentary disturbances, and infectious diseases. Malaria contributes to all three. It also results in an initially lowered vitality of the infant, a diminished power of an infected mother to suckle her babies, and a tendency towards general neglect of children if the mother is anaemic and weak from repeated attacks of malaria, or has died of the disease. When a mother is debilitated, she cannot carry out her normal maternal functions; and if the father is also a malarious invalid, unable to earn a full wage or to grow an adequate food crop, then the offspring start life under a severe handicap.

General effects on health

Sinton quotes a 1919 editorial in *Public Health Reports*:[5] "Competent investigators are of the opinion that the backward condition of school children in the coastal plains of the Carolinas is almost entirely due to the prevalence of malaria." And Sinton[6] himself has written :

"The disease has a marked effect upon the nervous system and the mentality of the individuals afflicted

[4] Bruce-Chwatt, L. J. (1954) *Brit. med. J.*, **1**, 169
[5] *Publ. Hlth Rep. (Wash.)*, 1919, **34**, 546. Quoted in Sinton, J. A. (1935) *Rec. Malar. Surv. India*, **5**, 425
[6] Sinton, J. A. (1935) *Rec. Malar. Surv. India*, **5**, 425

with it. It is easy to see how a child whose early years have been marked by a succession of weakening attacks of fever will probably enter adult life with a debilitated constitution and an ill-educated mind. It cannot be expected that children suffering chronically from this disease will be mentally capable of obtaining that benefit from literary teaching or other training that healthy children would derive. Apart from the mental state, attacks of the disease will seriously interfere with their attendance at school. It is not difficult to understand how the combined effects of physical weakness and nervous debility must hinder the powers of concentration and retard the normal development of the intelligence of such individuals."

Economic losses

Malaria undoubtedly results in severe financial and economic losses, direct and indirect, in any country where the disease is highly endemic. As an illustration of such losses, one may cite Russell & Menon's [7] malario-economic survey of a rural village in southern

[7] Russell, P. F. & Menon, M. K. (1942) *Indian med. Gaz.*, 77, 167

FIG. 2. MALARIA IN INDIA

A woman with malaria awaiting treatment (Tarai, India)

India: the annual payments per person to quacks, priests, and doctors for the treatment of malarial fevers was equivalent to US $0.80; and losses due to other money paid out and to cash wages not received because of malaria amounted to $1.24 per person per year. Malaria could certainly be controlled in this village by pyrethrum spraying to kill adult anophelines for about $0.08 per person per year. Few villages in India were on a much lower economic level than this one, where the total annual income per person was equivalent to only $11.26. Viewed simply as a matter of rupees and annas, malaria was a burden to this village.

Malaria is an expensive visitor in any country. For example, Howard,[8] a qualified observer, estimated in 1909 that malaria was costing the USA no less than $100 000 000 per year; and Williams,[9] whose career has been dedicated to the understanding and control of malaria, estimated in 1938 that these annual costs had risen to $500 000 000. Even now, when malaria is a rare disease in the USA, it still levies an enormous " hidden " tax on the people because imports such as basic minerals, hardwoods, coffee and cocoa, vegetable oils, waxes, and certain fruits which come from the malarious tropics are priced at least 5% higher than they would need be if it were not for the cost of malaria control —or lack of control, a greater expense—in the exporting countries, and because the market for every item of export to the tropics must naturally be smaller if malaria constitutes a heavy local financial burden on the people themselves and on their governments.

Balfour & Scott [10] calculated in 1924 that the direct annual cost of sickness and death due to malaria in India was between £50 000 000 and £60 000 000; and Sinton put the figure at £80 000 000, quite apart from indirect losses. What the latter involve can be imagined in the light of Ross's [11] statement, in 1910:

> " Malaria is the great enemy of the explorer, the missionary, the planter, the merchant, the soldier, the farmer, the administrator, the villager and the poor, and has, I believe, modified the world's history by tending to render the whole of the tropics comparatively unsuitable for the full development of civilisation."

Some recent examples of the economic aspects of malaria are of interest. For instance, in an epidemic of malaria in southern Egypt in 1942-43, one plantation alone suffered a monetary loss equivalent to $600 000 because most of the labourers were prostrated with chills and fever and were unable to harvest half of the wheat and a third of the sugar-cane crops. Several similarly striking illustrations were presented to the First Asian Malaria Conference, held in Bangkok in 1953.[12]

Mention might also be made of the numerous ways in which governments sustain financial losses because of malaria. For example, there are diminished revenues from taxation; greater expense for medical care; higher salaries and wages demanded for serving in unhealthy areas; slower development of natural resources ; impaired intellectual leadership; and retarded social development.

Hoffman,[13] in 1928, summed up the economic aspects of malaria control thus:

> " The cause of malaria eradication, therefore, rests upon sound economic as well as self-evident humane considerations, leaving no escape from the final conclusion that the entire subject most urgently demands the qualified and intelligent co-ordination of all existing governmental agencies and related

[8] Howard, L. O. (1909) *Bull. U.S. Bur. Ent.*, No. 78. Quoted in Sinton, J. A. (1935) *Rep. Malar. Surv. India*, **5**, 427

[9] Williams, L. L., jr (1938) *N. J. Mosq. Exterm. Ass.*, **25**, 148. Quoted in Boyd, M. J. (1949) *Malariology*, Philadelphia, vol. 2, p. 1387

[10] Balfour, A. & Scott, H. H. (1924) *Health problems of the Empire*, London. Quoted in Sinton, J. A. (1935) *Rec. Malar. Surv. India*, **5**, 428

[11] Ross, R. (1910) *The prevention of malaria*, New York. Quoted in Sinton, J. A. (1935) *Rec. Malar. Surv. India*, **5**, 431

[12] *Chron. Wld Hlth Org.*, 1954, **8**, 117

[13] Hoffman, F. L. (1928) *Malaria problems*, Newark. Quoted in Sinton, J. A. (1936) *Rec. Malar. Surv. India*, **6**, 157

health-conserving activities, on the one hand, and a broad-minded public policy, on the other, with specific reference, however, to the expenditures on behalf of local anti-malarial measures on the part of the general public. For economic reasons alone, the effort would be worth while, since the economic results of effective anti-malarial measures are a foregone conclusion."

METHODS OF CONTROL

OLD AND NEW METHODS

Malaria control has four principal historical roots—drainage, drugs, larvicides, and adulticides.

Drainage

The use of drainage to control malaria is a method that was first employed by engineers in ancient Rome. Although the construction of drains at that time was almost entirely for agricultural benefit, there are definite references in contemporary reports to some expectation also of relief from marsh-generated fevers. Vitruvius, for instance, wrote, " When the marshes are stagnant and have no drainage, they become putrid and emit vapours of a heavy and pestilential nature." Many attempts were made to drain the Pontine Marshes, beginning at the time of the Caesars; but success did not come until 1940, when the last great scheme was completed. This made possible the reclamation of about 200 000 acres of farmland supporting more than 50 000 people in an area where, in 1930, not a single permanent household could be found.

At the beginning of the twentieth century, there were extensive antimalarial drainage projects in many places, as widely separated as New York and Sierra Leone, Brazil and Hong Kong; and there followed a gradual but vast increase in such drainage up to the period of the Second World War. Particularly effective malaria control by subsoil drainage was accomplished in Malaya by numerous workers—Watson, in 1901, followed by Evans, Hunter, Scharff, and others.

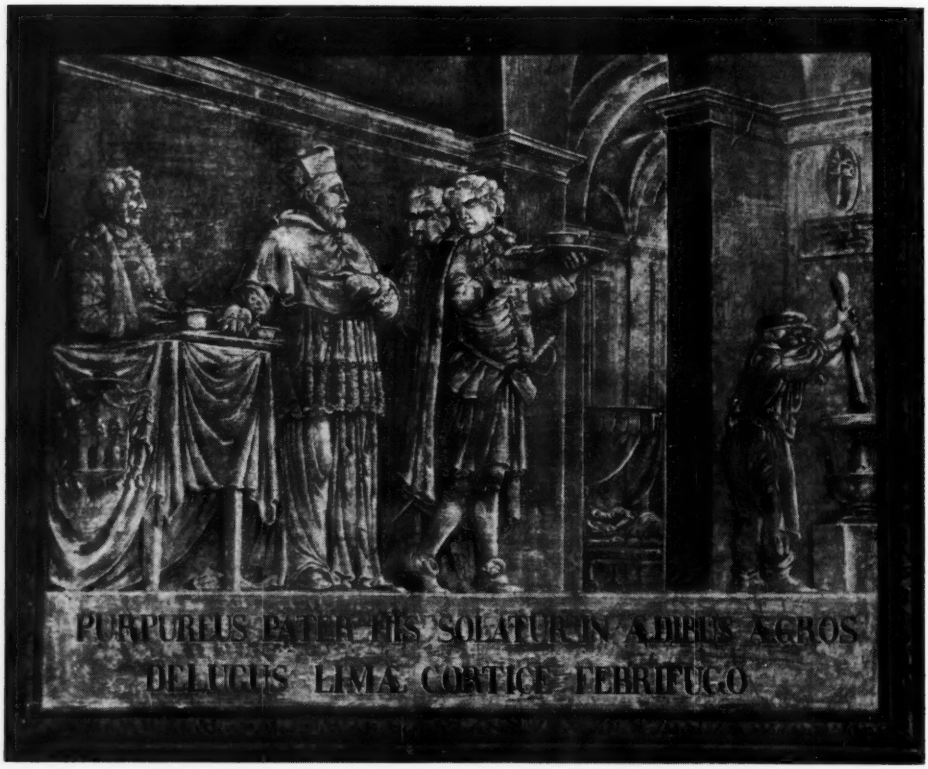
Drainage, however, is often expensive and by itself seldom gives full control of malaria, particularly in areas where the vector finds canals and ditches to be suitable breeding places. Today, as in ancient Rome, the chief usefulness of drainage is in the reclamation of land, not in malaria control.

Drugs

Attempts to prevent malarial illness by taking prophylactic drugs date back to at least 1768, when Lind recommended infusions and tinctures of cinchona bark for this purpose. Since the time when the alkaloid quinine became available, soon after its isolation in 1820, it has been widely used for malaria prophylaxis; but it has never had more than partial success.

The factors involved in the use of drugs to prevent malaria were at first not clearly realized. A better understanding of malaria has made it apparent that protective chemotherapy, or drug prophylaxis, has several forms. It may consist of an attack on the sporozoites or on the pre-erythrocytic stages. This, if successful, is *true causal prophylaxis.* The action of the drug may be on the multiplying forms in the red cells. Such *schizont blockage* is suppressive treatment or *suppressive protection* that does not necessarily eradicate the parasites but does prevent them from reaching a density sufficient to cause clinical symptoms. If the parasites are eliminated, the result constitutes *suppressive*

FIG. 3. EARLY USE OF CINCHONA BARK IN TREATING MALARIA



(Photo by courtesy of Professor P. Alonzo, Superintendent of the Sto Spirito Hospital, Rome)

The introduction of Cinchona *bark into the Sto Spirito Hospital in Rome by Cardinal De Lugo.*

cure. Finally, by attacking gametocytes, a drug may render a malaria carrier non infectious to mosquitos, even if it does not destroy all the parasites.

Quinine does not affect any exo-erythrocytic stages, is not very active against gametocytes, and disappears so quickly from the blood-stream that, when given prophylactically, it often does not effectively control the schizonts.

Other antimalarial drugs are mepacrine (Atabrine), chloroquine (Nivaquine B or Aralen), amodiaquine (Camoquine), proguanil (Paludrine), and pyrimethamine (Daraprim). Mepacrine, which was synthesized about 1930, was extremely useful during the Second World War. It was found that 0.1 g per day consistently prevents clinical symptoms of all types of malaria and, in addition, usually gives suppressive cure of falciparum malaria and occasionally of vivax. However, there was a high percentage of relapsing vivax malaria when the medication was stopped. Also, the drug has certain

disadvantages : it sometimes has undesirable toxic by-effects, and it temporarily causes a colouration of the skin. Chloroquine or amodiaquine, taken once a week in doses of 0.3 g or 0.4 g of base, respectively, give excellent suppressive protection against all types of malaria, with suppressive cure in most falciparum and some vivax infections and with a minimum of by-effects. Proguanil has been fairly widely used as a suppressive drug. Pyrimethamine is still under field trial.

Both proguanil and pyrimethamine have been reported to have induced a marked drug-tolerance in the plasmodia in certain areas, and this resistance to the drugs has been shown to remain even after the parasite has had several passages through vector mosquitos. Such resistance has not been noted with regard to any of the other drugs.

Apart from the question of drug-resistance, suppressive treatment of malaria is much more promising than heretofore. Nevertheless, except where relatively few cases are involved, it has not yet been shown that malaria can be eradicated from the average infected community solely by the use of drugs. In all but exceptional conditions, malaria control by antimosquito measures is still cheaper and more effective than medication. Modern synthetic antimalarials are, however, of great help as adjuvants in contemporary campaigns to eliminate malaria.

Larvicides

The earliest record of the use of larvicides to control mosquitos appears to be a note in Dunlap's American Yearly Advertiser, Philadelphia, 1793. In this case, " common oil " (whale oil ?) was used to kill larvae found in rain-water casks. Petroleum oils began to be used against mosquitos in the nineteenth century and were applied to breeding places on an enormous scale in malaria-control operations from 1900 onwards. They still have much usefulness under special conditions, but have been found unnecessary in malaria control wherever the

FIG. 4. SEARCHING FOR MOSQUITO LARVAE

Fishing for mosquito larvae (Malabar, India), part of the entomological work in modern malaria control

anopheline vectors can be destroyed by adulticidal sprays.

Powdered larvicides were apparently first used in the form of Paris green, by Marston, in New Orleans, early in the twentieth century. The first comprehensive experiments were performed by Barber and Hayne in 1921. Thereafter, until the end of the Second World War, Paris green was used in tremendous quantities in many parts of the world, distributed by hand, by various types of dusting machines, and by aeroplanes, with great success against anopheline larvae. But, as in the case of oil, Paris green has much less usefulness today, because experience has shown that malaria control is more effective and economical when the adults of the vector are attacked rather than the larvae.

Adulticides

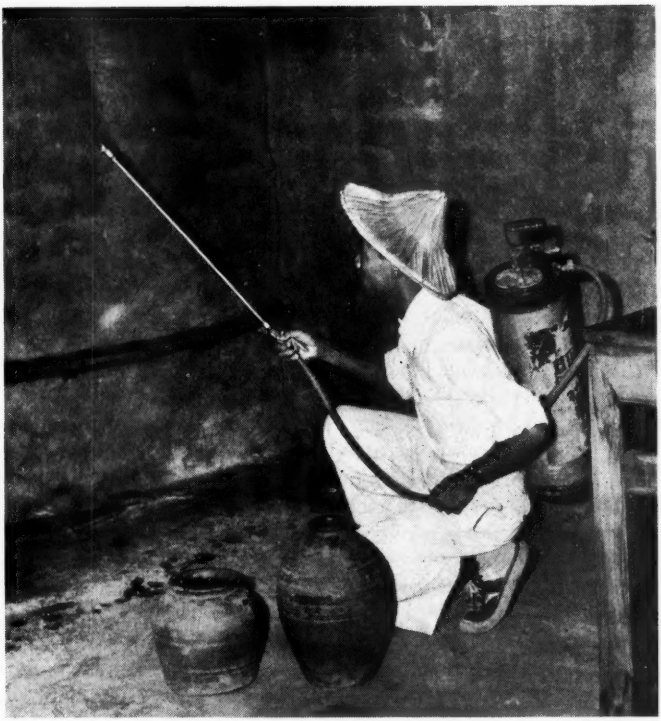
The first method of mosquito control used by man was, perhaps, the destruction of adult mosquitos by hand. This was one of the measures employed systematically by Gorgas and his colleagues during the construction of the Panama Canal; the labourers' quarters were regularly visited by men whose job it was to kill as many of the resting adult anophelines as possible. Other measures directed against adult mosquitos, such as the use of bed nets and screens and the application of repellents to the skin, have been, and still are, important aids to individuals in malarious places.

Killing adult mosquitos has become the most effective and most widely used method of controlling malaria, and adulticidal sprays have proved the most satisfactory means of achieving this purpose. The first mosquito spray to have wide application was a petroleum oil extract of pyrethrum. Park Ross and De Meillon made the earliest practical use of this adulticide in communities in South Africa, as reported at the Pan African Health Conference of the Health Organisation of the League of Nations in November 1935. They obtained excellent results by systematic house-to-house indoor spraying. De Meillon pointed out that " the whole idea underlying malaria control by anti-adult measures " is that " it is not intended to destroy all *A. gambiae* but only those which are infected, which past experience has shown are largely to be found indoors ". He also noted that the cost of anti-adult spraying was about a third of that of the less effective antilarval control.

Experiments with similar pyrethrum spraying in India confirmed its usefulness against those malaria vectors that, like *A. culicifacies*, rest for the most part indoors in the daytime. Costs of this type of malaria control were found to be amazingly low—less than US $0.10 per person annually under typical, rural, south India conditions. During the Second World War, much use was made of this type of prophylaxis : no fewer than 40 million 1-lb aerosol pyrethrum " bombs " were supplied to the Allied Armed Forces.

DDT (dichloro-diphenyl-trichloroethane) was synthesized by Zeidler in 1874 but remained obscure until 1936-37, when Paul Müller, in Switzerland, discovered that it was an amazingly effective insecticide—an observation for which he received a Nobel Prize. The special importance of DDT derives from the fact that it has a prolonged residual killing effect on many insects when it is sprayed on surfaces upon which they later walk or rest. DDT does not kill mosquitos more quickly than pyrethrum; but, unlike the latter, it continues to kill for months after it has been applied to surfaces in suitable formulations. Using DDT sprays, one does not have to hit insects directly with spray particles to kill them; it is anticipated that a significant number of malaria vector mosquitos will rest on the DDT-treated surface at some time during the period of ten days or more required for the development of infective sporozoites. Particles of the toxicant

FIG. 5. MALARIA CONTROL BY RESIDUAL ACTION ADULTICIDES



Spraying with DDT in Taiwan

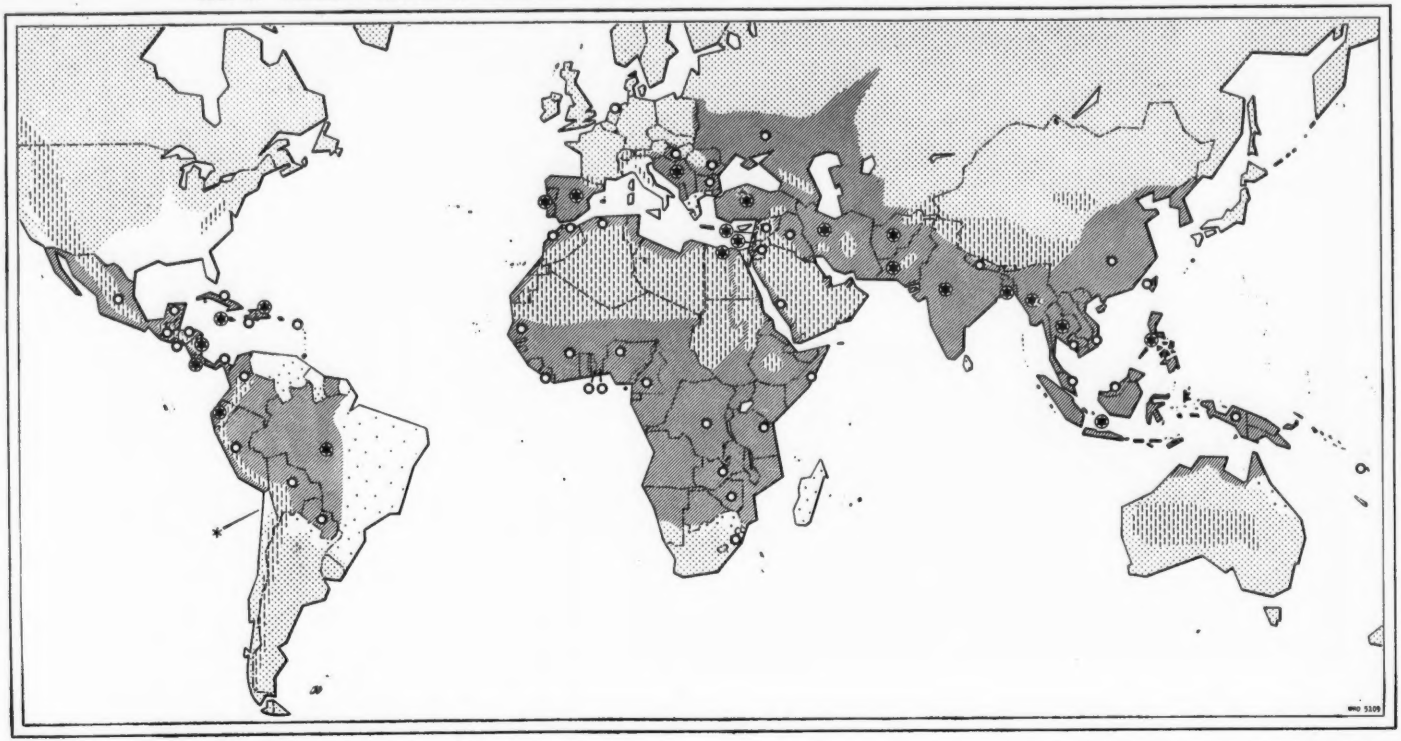
cling to the feet of the insect, which may also transfer them elsewhere on its body. The poison penetrates the cuticle and is absorbed, with fatal results. Other useful insecticides having similar residual action are benzene hexachloride (BHC), chlordane, and dieldrin.

All four of these adulticides have been used to control *Anopheles*. There is probably no malarious country today in which one or another is not being employed against malaria, in many cases with complete success.

However, the spectre of insect resistance to the residual toxicants, which will be discussed later (see page 90), is now a matter of concern. High percentages of the local populations of certain species of house-flies, *Culex* mosquitos, and certain other noxious insects in a number of areas are not now killed by the insecticides mentioned above. In some cases, flies have become highly resistant after one to three seasonal sprayings with DDT. Moreover, when resistant to one of the chlorinated hydrocarbons, flies quickly become tolerant to the others.

One malaria vector, *A. sacharovi*, has begun to show such a tolerance to DDT in Greece that in some areas residual spraying with this chemical can no longer be recommended for control of malaria carried by this anopheline. In parts of Lebanon the same species seems to be developing resistance after only two years of DDT spraying. Another malaria vector, *A. albimanus*, in Panama, has developed a tendency to avoid DDT-treated surfaces, contrary to its behaviour at

FIG. 6. PRESENT STATUS OF MALARIA CONTROL, BASED MAINLY UPON USE OF RESIDUAL INSECTICIDES



Territories which were free of malaria before 1946

Territories where malaria transmission is precluded because of altitude or desert conditions

Malarious territories

Territories which were malarious before 1946 but from which malaria has now been eliminated

Territories which were malarious before 1946 but in which malaria morbidity has been drastically reduced

Malaria-control operations by residual insecticide spraying now under way

Plan aiming at nation-wide malaria-control now being implemented

This map does not claim to be complete. Sufficient data are not available on malaria control in the USSR, in the People's Republic of China, and

* Chile was the first country to eradicate malaria in the small area where the disease was present, but by antilarval work, before DDT.

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first. While only one or two other *Anopheles* species have shown resistance or behaviour changes of practical importance following DDT spraying, the possibilities of the development of such resistance are of great significance in malaria control. Although this resistance to DDT may develop in houseflies after only a year or two of spraying, it is usually slow to appear in *Anopheles* mosquitos. If a country-wide malaria-control programme by residual spraying is systematically pushed to completion in a matter of seven or eight years, there is not much chance of failure because of insect resistance to the toxicants.

The sorption of insecticides by certain types of mud-wall surfaces is another problem that complicates the use of residual DDT (see page 87).

A final comment on adulticides is that, when malaria transmission has been ended in an extensive area, it seems reasonable to believe that the spraying can safely be discontinued, provided adequate provision is made to detect promptly the appearance of malaria derived from imported cases or neglected foci (see page 92).

MALARIA ERADICATION

In the past, except in areas of low or restricted incidence, it has been necessary for economic and technical reasons to set up as the objective of malaria control amelioration rather than eradication, hoping that in time the maintenance of effective measures might result in the disappearance of malaria. This hope was reasonable in countries with climatic conditions unfavourable to the transmission of malaria, but it was Utopian in the tropics. Now, however, it has become possible to think more and more in terms of malaria eradication, regardless of the latitude involved.

The term " malaria elimination ", or " malaria eradication ", should not be confused with the expression " vector eradication ". The latter method of malaria control aims at complete extirpation of vector species from given areas, and it is not an economically feasible proposition except under unusual conditions. *Anopheles gambiae*, for example, was completely destroyed in north-eastern Brazil after it had invaded that country from Africa; and the same invader was driven out of southern Egypt. In neither case was malaria due to other anopheline species eliminated. However, vigorous attempts to extirpate indigenous anopheline vectors from Cyprus and from Sardinia eliminated malaria but failed to destroy all the anophelines, in spite of exceptionally strong antimosquito organizations and ample funds.

In certain small areas with effective natural barriers, stable vector eradication might be achieved at a reasonable cost. But in the average malarious country, it appears to be much cheaper to aim at eradicating malaria by residual spraying, not being concerned about the mosquitos that remain. In the absence of gametocytes, the persisting mosquitos cannot transmit malaria. In some instances, residual spraying has apparently eradicated certain species of vectors without any special attempt being made to do so: for example, *A. darlingi*, in most of Venezuela and British Guiana, and *A. labranchiae*, in the Pontine Marshes area, have disappeared during residual spraying.

A country-wide, energetically applied, residual spray programme may be expected, on the basis of recent experience, to bring about the eradication of malaria in most countries in seven or eight years. For instance, in 1953 in Italy, after systematic spraying with DDT since 1946, there were only 12 cases of indigenous malaria (primary or relapses) reported—an amazing contrast to the 303 057 malaria cases reported in 1919 and the 411 602 cases reported in 1945.

In some communities it may be advisable

● *Plan aiming at nation-wide malaria-control now being implemented*

This map does not claim to be complete. Sufficient data are not available on malaria control in the USSR, in the People's Republic of China, and

to supplement residual spraying with selective treatment of those who have relapsing malaria. Exceptionally, gametocyte carriers may also be sought out and treated. In primaquine there is now available an antimalaria drug that, administered under proper supervision, will in many cases completely free the body of plasmodia.

NATIONAL AND INTERNATIONAL ACTION AGAINST MALARIA

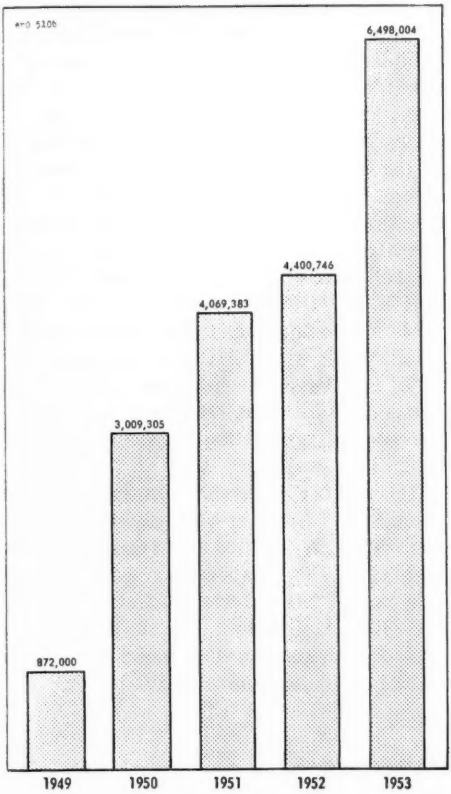
The new weapons in malaria control—residual insecticides and new antimalarial drugs—have made feasible, and even essential, control campaigns on a scale larger than would have been thought possible fifteen years ago. Since the Second World War, most malarious countries have embarked upon extensive malaria-control programmes, in many instances with international or bilateral assistance. This assistance has taken the form of technical guidance and financial aid in actual control operations, and also, in the case of help from WHO, of training personnel for malaria work and promoting the exchange of knowledge of modern malaria-control methods.

The sections which follow give an account of some of the considerable accomplishments in recent years in national and international efforts to control malaria and describe the part that WHO is playing. The success of international assistance in malaria control is measured not merely by a decrease in the prevalence of the infection, but also by the continuation of control measures by the health administrations concerned after international aid comes to an end. It will be noted that all the governments have continued, and even extended, the malaria-control measures initiated with international help, and that in most countries nation-wide programmes have been developed. This continuity, as well as the efficiency of operations, is dependent upon the existence of an adequate malaria-control organization within the country, and aiding in the establishment or strengthening of such organizations is one of the essentials of international assistance.

WHO and UNICEF co-operate in many malaria-control schemes, the former providing technical advice and the services of expert personnel, and the latter furnishing insecticides, spraying equipment, transport, and other necessary supplies. Since 1951 Technical Assistance funds have enabled the Organization to provide equipment and supplies as well as personnel for some projects; but, for the most part, WHO depends on the governments concerned and on UNICEF for the materials necessary for malaria control. Besides the projects in which UNICEF assists governments by giving supplies and equipment and WHO by assigning personnel, there are a number of national antimalaria programmes which are benefiting largely from UNICEF's material assistance and which have been established according to plans having the technical approval of WHO. This is the case for some countries in Asia, for some territories in Africa, and, particularly, for numerous countries in Latin America.

The United Nations Food and Agriculture Organization (FAO) has participated in some WHO technical meetings on malaria. Malaria control is often a prerequisite for the adequate production of food: in parts of the world the disease interferes greatly with agriculture by impeding the development of uninhabited and fertile areas and by reducing the working capacity of the rural population.

FIG. 7. NUMBER OF PERSONS DIRECTLY PROTECTED IN WHO-AIDED MALARIA-CONTROL PROJECTS, 1949-53



This graph does not include populations protected by national malaria-control projects after the withdrawal of international personnel. Some of the figures included for the Region of the Americas and for malaria control among the Palestine refugees (UNRWAPRNE operations) are provisional.

Valuable support in malaria-control programmes is also given by other agencies, particularly those concerned with bilateral technical assistance. In a number of countries —India, the Philippines, Viet Nam, and Taiwan, for example—USA bilateral assistance is supporting national malaria-control projects with expert personnel, equipment, and supplies. Where WHO teams are also assisting, the two agencies co-operate, each making use of the findings of the other,

FIG. 8. ANNUAL INTERNATIONAL EXPENDITURES FOR MALARIA CONTROL, 1949-53

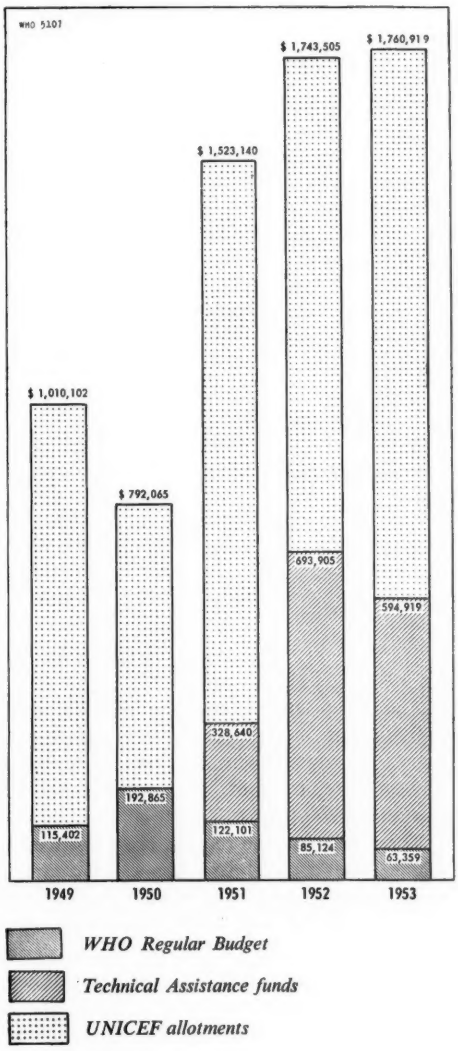
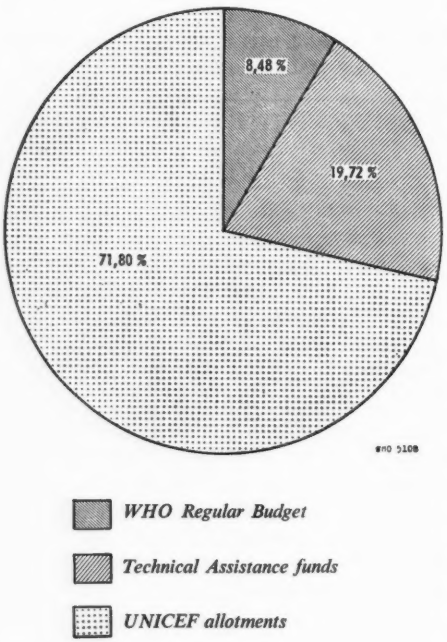


FIG. 9. SOURCES OF INTERNATIONAL FUNDS FOR MALARIA CONTROL, ON A PERCENTAGE BASIS, FOR THE PERIOD 1949-53



especially with regard to malaria epidemiology and the usefulness of residual insecticides and methods of application.

A critical problem in malaria control is assuring a free flow of insecticides and equipment for applying them from producing countries to those which have need of these items. This problem has been the subject of action by the Economic and Social Council of the United Nations, which has helped to assure that the necessary quantities of insecticides are made available to governments requiring them. In addition, through the collective efforts of the United Nations, WHO, and UNICEF, an attempt has been made to promote the regional production of insecticides : with WHO technical guidance, UNICEF financial aid, and funds from Technical Assistance, DDT-producing plants are nearing completion in Ceylon, Egypt, India, and Pakistan.[1]

The number of persons protected and the countries concerned in WHO-assisted malaria-control projects, carried out in many instances with UNICEF collaboration, over the five-year period 1949-53 are illustrated in fig. 7 and 10. Also shown (fig. 8 and 9 are expenditures for this work and a breakdown according to the source of funds.

CONTROL CAMPAIGNS

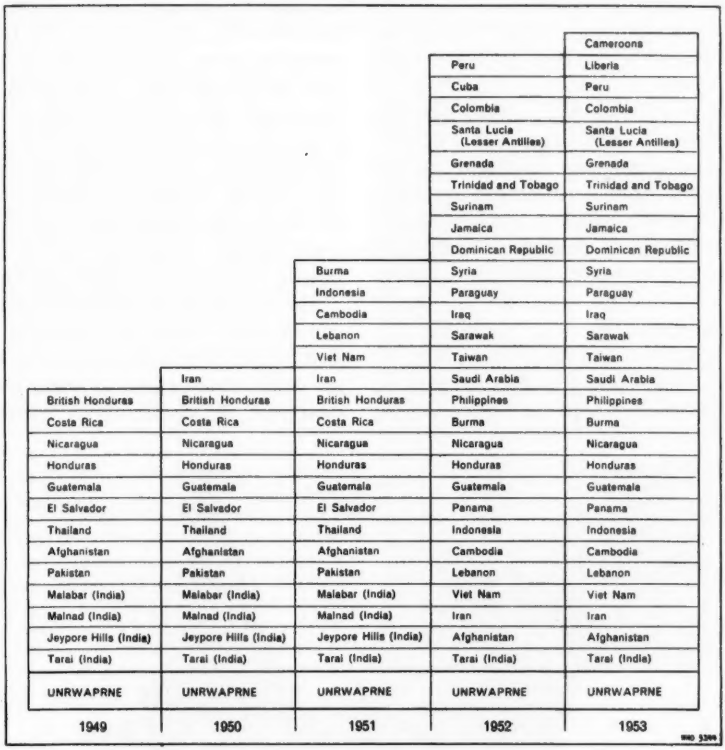
The chief instrument in WHO's field activities in malaria control is the expert team, of which there are two types—the advisory team, and the malaria-control demonstration team.

The former, at the request of governments which have decided to embark upon large-scale programmes, are sent to assist in making malarial and entomological surveys, planning projects, strengthening malaria organizations, and training personnel. They are not provided with operational equipment or supplies since their role is largely one of technical guide, and they are generally sent to the capital of the country so that they can work with the central public-health administration.

Demonstration teams, on the other hand, are provided with their own equipment and transport, and work in selected areas of high malaria endemicity, where they demonstrate modern methods of malaria control at the lowest feasible cost, assess the results, train local personnel, and advise, upon

[1] See *Chron. Wld Hlth Org.*, 1953, **7**, 327. WHO aid in this project came to an end in July 1953.

FIG. 10. MALARIA-CONTROL PROJECTS ASSISTED BY WHO, OFTEN WITH UNICEF COLLABORATION, 1949-53



government request and with regional office sanction, on other problems as well as malaria. Sometimes these teams must determine how malaria can best be controlled under particular epidemiological conditions, and to this end they undertake what are known as " pilot projects ".

It will be seen in the description of malaria-control activities which follows that in all the projects malaria has been controlled, and that in some malaria transmission has probably been interrupted. Repeated malariometric and entomological surveys have put at the disposal of the governments a picture of malaria epidemiology in the project area and have shown what could be expected from the methods adopted, and at what cost. Training of national personnel has been part of all projects, so that the work might be continued after withdrawal of the international team.

MALARIA-CONTROL DEMONSTRATIONS

Demonstrations are conducted by teams composed of a senior staff of international experts, provided by WHO, and of local " opposite numbers ", seconded by the

government. As the opposite numbers become thoroughly trained, they gradually assume responsibility for the work.

The same methods of survey and evaluation are followed by practically all the teams, in the interests of achieving uniformity in the collection of data and making possible accurate appraisal and comparison of data from different countries. Arrangements are always made to have a comparison, or check, area, which is left unsprayed but which is subjected to the same observation as the area where spraying operations have been carried out.

Malariometric data are collected for children (separated into two groups, 2-4 and 5-9 years), and great attention is paid to infant parasite-rates. In order to obtain statistically significant samples, an attempt is made to examine a minimum of 10% of all children between 2 and 10 years of age—possibly 20% for spleen-rates. In addition, monthly infant parasite-rates are taken in selected villages; and, in the same villages or in others, the course of malaria morbidity is studied by periodic visits during which all cases of fever are registered and the blood of the patients examined. Generally, surveys of adults are undertaken only when their malariometric rates are useful in characterizing the type of malaria endemicity.

The procedures for obtaining and recording entomological data are similarly standardized : stations for collecting imago and larvae are established as part of every project, and dissection of mosquitos is carried out to

FIG. 11. MALARIOMETRIC SURVEY

Examining children for determining spleen-rates (Thailand)

determine the vector and define the season of transmission. Outlet window-trap catching in sprayed and unsprayed houses, though tried everywhere, has not always proved successful.

Team members are also responsible for the collection of meteorological and other relevant data, such as information on health conditions in general, and prevalence of insect-borne diseases in particular, on environmental sanitation, and, if possible, on social, economic, and agricultural conditions.

Information on spraying operations is recorded in a uniform manner by each team, as follows:

Summary: (1) number of villages sprayed; (2) number of houses and/or structures sprayed; (3) number of rooms and compartments sprayed; (4) population directly protected (i.e., number of individuals residing in sprayed houses); (5) superfiical area sprayed, in square metres; (6) DDT used, in terms of technical grade DDT, kilograms, as wettable powder, as emulsion, or as solution; (7) technical DDT sprayed, average grams per square metre; (8) number of workers, including squad leaders; (9) man-hours worked, squad leaders and others; (10) man-hours of disinfestors; (11) number of hours spent travelling; (12) area of operations, square kilometres; (13) date spraying started; (14) date spraying completed; (15) total number of working days employed; (16) types of sprayers used (specifying also type of nozzles).

Analysis : (1) average number of rooms and compartments per structure; (2) average superficial area sprayed per structure, in square metres; (3) average number of inhabitants per structure; (4) DDT technical grade used per structure, grams; (5) man-hours labour per structure (including squad leader); (6) disinfestor man-hours per structure; (7) average superficial area treated per person protected, square metres; (8) superficial area treated per man-hour, including squad leader, in square metres; (9) superficial area treated per man-hour of disinfestor, square metres; (10) technical DDT used per person protected, grams; (11) proportion of time spent for travel to total time of operations.

An evaluation of the costs of spraying operations is an important part of the teams' work, so that governments may be able to estimate how much it will cost them to repeat the operations. The analysis of expenditures includes:

(1) cost of labour employed for the actual spraying;

(2) equipment, in terms of its depreciation, the yearly depreciation generally suggested being as follows: vehicles, 24% (2% per month), bicycles, 30%, sprayers, 25%, other items, 5% to 30%;

(3) supplies;

(4) transport (operation and maintenance for the work related to the actual spraying operations);

(5) supervisory staff (The number of personnel in the national supervisory staff should be based on the actual requirements in the area of operations : if the size of the supervisory staff employed in the project was such that it could have covered a popula-

FIG. 12. ENTOMOLOGICAL SURVEY

Searching for adult mosquitos in outlet window-traps (Philippines)

tion greater than that in the demonstration area, the salaries are pro-rated to obtain the amount corresponding to the services rendered to the population in the area of operations. The salaries should be computed in conformity with the prevailing national schedule);

(6) miscellaneous expenses.

This information, too, is recorded uniformly by all WHO teams.

There follow brief histories of some of the WHO malaria-control demonstrations.

Afghanistan

Very little was known, or done, about malaria in Afghanistan before 1949, when, at the request of the Government, WHO sent a malaria survey team for a short-term assignment beginning in May of that year. Three months later a small demonstration team made a quick preliminary survey of the hyperendemic malaria area of Laghman, Jalalabad province, and then proceeded to carry out the first residual spraying of houses, protecting about 13 000 persons. *A. superpictus* and *A. culicifacies* were both found infected in the area.

The project was very successful, and the Government took it over in 1950. WHO personnel was sent to another area, in northern Afghanistan, for a full demonstration project. In this instance, the Organization provided equipment and supplies as well as a team. The area selected for the demonstration was in the province of Katagan and contained the two districts, or " hakumati ", of Khundus and Khanabad.

A preliminary survey showed spleen-rates ranging from 25% to 33% in the Khundus area and exceeding 50% in Khanabad town and surrounding villages; parasite-rates averaged 8.9%. During the whole period of activity of the team, thousands of dissections of the two main anophelines believed to be vectors, *A. superpictus* and *A. pulcherrimus*, failed to show any *pulcherrimus* infected, while *superpictus* was repeatedly found with sporozoites.

Houses were mud-built and large, with the sprayable surface area per person being about 70 m². The first year, approximately 45 000 persons were protected. In the second year, 1951, it was already known that the transmission season in Katagan lasted about three months, from the last part of July until the end of October; and it was decided that, in the area which was going to be sprayed before 15 June, 2 g of DDT per m² should be applied, but that, in the area to be sprayed later, 1 g per m² would be sufficient. In addition, a small area was to be sprayed with only 0.5 g per m², and here the operations were to be repeated six weeks later. The 1951 spraying was carried out according to this scheme and lasted from 10 May to 22 July, with the second round of 0.5 g per m² being applied in August.

It was found that, owing to the large sprayable area, the overall consumption of technical DDT per person per year was 93 g, and the cost per person protected equivalent to US $0.20; it was also found, however, that in future a single application of only 1 g of DDT per m² would be sufficient.

The results after two years' spraying were very satisfactory. Approximately 150 000 persons were protected in 1951. The spleen-rate decreased by 24.8% in the sprayed area, while it increased 18% in the unsprayed check area; the parasite-rate dropped from 8.9%, to 0.8%, while in the check area it rose from 11.8% to 13.1%; and the infant parasite-rate became nil, while it was still 15.2% in the check area. There was a remarkable decrease in clinical malaria and in anopheline density in the sprayed area.

Progress had also been realized in establishing malaria-control services: a nucleus organization had been formed, and a malaria institute was being set up.

In these two years, the WHO team, while devoting its activity only to malaria control in the appropriate season, stayed in Kabul during the winter and gave training courses

for malaria personnel and sanitary inspectors and instructed school teachers in hygiene. It also assisted in antityphus operations in Kabul and Kandahar.

Towards the end of 1951, the original malaria-control demonstration was terminated and a national malaria-control campaign was being planned, with WHO personnel acting in an advisory capacity. The Government requested assistance from UNICEF for the national campaign.

The nation-wide scheme, starting from a level of 675 000 persons protected in 1952, and with progressive yearly expansion rendered possible by UNICEF's contributions, aims at protecting all the population of the endemic areas (about two million persons) in 1955. In 1953, 274 000 persons were protected in addition to those already covered by the 1952 operations—a total of more than 949 000. UNICEF contributed US $22 000, and the national budget for malaria control was the equivalent of US $165 000. It is understood that UNICEF proposes to continue its assistance in 1955, and to maintain it on a decreasing scale from 1956 to 1958. The costs of the campaign are gradually decreasing: in one province, where the sprayable area is large, the cost per person in 1953 was US $0.15; in another province, with a smaller sprayable area, it went down to $0.083.

An interesting feature of the organization of the nation-wide plan is that the post-operational surveys are carried out independently, that is, by teams which were not responsible for the relevant control operations. In 1953, there were seven such teams in the field, each composed of a medical officer and three technicians. The malaria organization was well established by the end of the year, comprising, in addition to its president, 6 medical officers, 1 entomologist, and 49 technicians, all adequately trained and already manning a number of teams operating in the country. Furthermore, the malaria institute was almost completed, partial occupation of the building having begun in December 1953.

Burma

A malaria-control demonstration began in Burma in October 1951, when a WHO international team arrived in Lashio, capital of the Northern Shan State. Equipment and supplies for the work were provided by the Government, with bilateral assistance from the USA up to 30 June 1953 and from UNICEF after that date.

The area chosen for the demonstration was hyperendemic. Houses were built on bamboo poles and were made of bamboo mats and thatched roofs. The first survey, started in December 1951, showed, in the rural areas, spleen-rates of about 90%, a parasite-rate of 27%, and an infant parasite-rate varying from 31% to 35%.

Of 23 species of anopheles present, only *A. minimus* was found infected; sporozoites were found in its salivary glands during all months except April and May. It was discovered that *A. minimus* preferred houses to cowsheds, and that in houses most of them (80%-90%) rested on the walls at a height lower than a metre. This indicated a need for experimenting with selective spraying methods, and several were tried.

The first spraying took place from 17 March to 13 May 1952, and 55 267 persons were protected. A second spraying, between 8 January and 23 March 1953, protected 110 429 people. During this cycle, spraying operations were based upon the results of previous trials, and most of the area was sprayed with 2 g of DDT per m^2, applied to all interior surfaces; only one sector, with 14 000 inhabitants, was still sprayed by a selective method, up to about 2 m and using the same dosage. Cattle sheds were not sprayed anywhere. The third spraying cycle

was from 3 January to 25 February 1954, and 114 288 persons were protected.

The results were satisfactory, as can be seen from the following data.

	Spleen-rate (%)	*Parasite-rate* (%)	*Infant parasite-rate* (%)
1. Area first sprayed in 1952 and 1953, 2 g DDT per m²			
Pre-spraying survey (1951-Jan. 1952)	90	26.5	35.2
FIRST SPRAYING			
Second survey (Dec. 1952-Jan. 1953)	66.6	3.7	0
SECOND SPRAYING			
Third survey (Dec. 1953-Jan. 1954)	12.1	5.8	0
2. Area first sprayed in 1953, 2 g DDT per m² (comparison area in 1952)			
Pre-spraying surveys (1951-Jan. 1952)	90	25.6	41.2
(Dec. 1952-Jan. 1953)	82.5	43.4	46.0
FIRST SPRAYING			
Post-spraying survey (Dec. 1953-Jan. 1954)	50.2	15.3	9.2
3. Areas sprayed with various types of selective spraying in 1952; all with 2 g DDT per m² up to about 2 m in 1953			
Pre-spraying survey (1951-Jan. 1952)	88.5-94.5	17.9-33.8	9.1-40
FIRST SPRAYING			
Second survey (Dec. 1952-Jan. 1953)	64.8-70	3.6-8.14	6.3-12.5
SECOND SPRAYING			
Third survey (Dec. 1953-Jan. 1954)	0-8.6	0-2.6	0

It is apparent that selective spraying (i.e., houses only up to about 2 metres) and no treatment of cowsheds gave results comparable to those obtained by spraying all inside wall surfaces.

The average cost per person protected was the equivalent of US $0.232 and $0.238 in 1952 and 1953, respectively.

It was found that on the type of wall common in the area DDT at 2 g per m² remained active against *A. minimus* for at least thirteen months. The vector species was practically absent in the sprayed area. In February 1954, no *A. minimus* were found during 158 man-hours of day-time searching (nor in 17 whole night collections) in houses of the sprayed areas, whereas, in unsprayed villages, 9.8 were found per man-hour of search. Larval density was also greatly reduced (50%).

Throughout the project, work in environmental sanitation and community organization was successfully carried out.

In 1952, the senior adviser of the WHO team drew up, with the relevant Government and bilateral assistance representatives, a five-year plan for the control of malaria in all the endemic areas of Burma. In April 1954, the Government took over the Lashio area as part of a national malaria-control programme, and WHO personnel were transferred to a new project in Maymyo, where emphasis was put on training personnel to be employed for the nation-wide programme. The latter, which is assisted by UNICEF, provides for the protection of 2.7 million persons in 1954 and, by 1957, of all the 7.5 million people of Burma who are exposed to malaria.

Cambodia

Assistance in malaria control to Cambodia began with the sending of a malaria adviser from October 1950 to May 1951. A few months later, in August, a team consisting of a malariologist and a public health sanitarian started a malaria-control demonstration which lasted until March 1953. The Government assigned to the project as "opposite numbers" a medical officer and a supervisor

It was known that the main vectors were *A. minimus minimus* and, on the littoral,

A. sundaicus, and that transmission probably occurred during all twelve months of the year. Still, the lack of an entomologist, national or international, was a serious handicap to the proper working of the project.

Even more serious were the political conditions of the country. The demonstration area was composed of four non-contiguous zones, distributed in the provinces of Takeo, Kampot, Siemreap, and Kompongcham. Three comparison areas were established at the beginning of the project, but one later proved unsuitable, another had to be abandoned because security reasons made it inaccessible, and the third, with a population of 5600, was somewhat too small to provide statistically significant data. Political and military conditions made it impossible to select the most suitable areas for the demonstration, so that only those areas that were safely accessible could be selected. The same conditions dictated sudden transfers of population. Villages that had been sprayed became invaded by refugees, who set up huts in great numbers, thus affording, without the knowledge of the team, unsprayed premises where vectors could survive.

The spraying operations were carried out twice a year. The senior adviser believed that this repetition was necessary (1) during the dry season, because of deposits of heavy red dust on the surface of the walls, which are generally (in about 70% of cases) made of palm leaves, with or without split bamboos, and (2) during the rainy season, which lasts six months, because water would leak along the inner walls and these are often replaced by new layers of palm leaves. DDT was used at theoretical doses of 2 g per m². Costs were high: the equivalent of US $0.427 per person protected per year (for the two sprayings). The surface to be sprayed, on a per person basis, was not too large; but the population density was very low—an average of 20 per km² in malarious areas, and only 5 per km² in some places.

Epidemiological study and assessment of results of this project were necessarily reduced to a minimum, which explains the sparsity of items in the following summary, which gives the total data for the demonstration area, in the four sectors.

	Pre-operational survey	*Post-operational survey*
Children (2-14 years)		
Number examined	1090	1458
Spleen-rate (%)	57.4	25.8
Number examined	778	1360
Parasite-rate (%)	31.1	16.4
Infants		
Number examined	130	117
Parasite-rate (%)	26.2	8.4

At the end of the demonstration, the Government requested its resumption. Thus a third phase of WHO assistance to the Government of Cambodia started in August 1953, when two malaria experts arrived in Pnompenh. A new demonstration area with a suitable comparison area was chosen in the " srok " of Snuol, Kratié. The rest of the country, wherever possible, is to be surveyed; and malaria-control operations are to be carried out in all areas where the spleen-rate exceeds 10%. A single yearly spraying is being tried.

China (Taiwan)

Malaria is a serious problem in Taiwan: it is estimated that 10% of the population—i.e., about 800 000 persons—suffer from it yearly. In an over-populated country like Taiwan, where there is an excess of labour and where no arable land is left uncultivated, it is difficult to investigate economic conditions related to malaria alone. However, a survey intended to determine the economic losses caused by a malaria epidemic in Kao-Hsu township revealed that it cost 5256 persons the equivalent of US $17 500 within four months for treatment, loss of labour,

doctors' fees, and other relevant expenses—a sum equal to nearly five and a half times the cost per person of a yearly spraying with DDT (figured at $0.175 per person protected).

A WHO-aided project, planned for four years, started on 15 May 1952, with a team, consisting of a malariologist, an entomologist, and a public health engineer, and a certain amount of supplies furnished by the Organization, through Technical Assistance funds. The Government appointed as counterparts to the international staff the present Director of the Provincial Malaria Research Institute in Ch'ao-Chow, where the headquarters of the team is located, 4 other malariologists, 3 engineers, 14 technicians for parasitological and entomological activities, 14 field supervisors, and the necessary administrative and operational personnel.

In the same year, 1952, a nation-wide "Four Year Malaria Eradication Programme" was adopted. This programme is being implemented by the Government, through the aforementioned malaria institute, with substantial financial assistance from the Foreign Operations Administration (FOA) of the USA and with technical assistance and some financial help (in 1952 and 1953) from WHO.

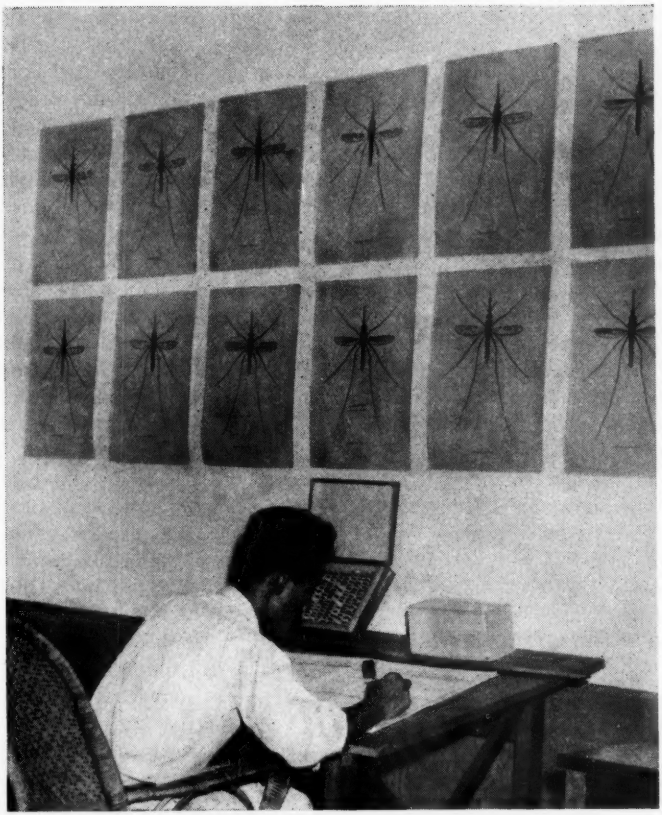
The WHO demonstration area consisted of the Chi-Shan district of Kaohsiung prefecture, near Ch'ao-Chow, where spleen-rates among children varied from 17.27% to 100%. The vector species were *A. minimus* and, less frequently, *A. hyrcanus sinensis*, though no specimen of the latter was found with infected glands by the project entomologists. A sector of the district was left unsprayed as a control.

During the first spraying cycle (14 July-28 September 1952), 37 282 people were protected in the highly malarious district of Chi-Shan. In addition, six townships around Ch'ao-Chow were sprayed. In all, 156 217

FIG. 13. MALARIA CONTROL IN TAIWAN—I

Reading of blood samples in the Taiwan malaria-control project

FIG. 14. MALARIA CONTROL IN TAIWAN—II



Identification of captured anophelines in Taiwan

persons were protected, at a cost of about the equivalent of US $0.158 per person protected.

In the pre-operational survey in June 1952, the infant parasite-rate was found to be 9.34% among the 814 infants examined. In November 1952, the infant parasite-rate was 0.35% in the sprayed area, whereas in the check area it was 5.62%. Of 288 infants, only one, born in May before the spraying, was found positive for *vivax*. In December 1953, the infant parasite-rate in the demonstration area was nil (307 infants examined), as compared with 4% in the unsprayed area. From that time on, the infant parasite-rate in the demonstration area remained negative.

In areas sprayed during 1953 for the first time, 867 infant smears were all negative four or five months after spraying. As in Thailand, *A. minimus* practically disappeared from the sprayed areas, while it showed a very high density in the check area.

It had been found that *A. minimus* was highly selective in its resting places indoors. About 60% of all specimens caught during the day were in bedrooms; most of those caught indoors were captured under beds,

tables, or shelves. In stables, *A. minimus* was rare, while *A. hyrcanus sinensis* was very abundant. On the basis of these findings, selective spraying was tried in 1952. Owing to the promising results of this experiment, a second demonstration area was sprayed selectively in 1953. Under this scheme, all of the walls and ceilings of the rooms where people slept were sprayed, as were storerooms, the undersides of furniture in sitting rooms and kitchens, and, for general sanitation purposes, food cabinets and toilets. Other spaces, stables, etc., were left unsprayed.

It can be seen from the following cumulative data from the Chi-Shan district that the results of the selective spraying were as good as those of the complete spraying. From the entomological standpoint as well, the selective spraying gave the same results.

	June-Sept. 1952 (pre-spraying)	*Oct. 1952-Oct. 1953*	*Nov. 1953-Aug. 1954*
		First spraying	*Second spraying*
1. Complete spraying			
Number examined	833	2487	1725
Infant parasite-rate (%)	9.6	0.4	0.0
2. Selective spraying			
Number examined	400	1836	1236
Infant parasite-rate (%)	9.5	0.44	0.0
3. Check area			
Number examined	491	1997	1529
Infant parasite-rate (%)	7.94	2.55	0.13
		No spraying	*First spraying*

The cost per person protected in 1953 was US $0.18 for the complete spraying, and $0.134 for the selective spraying—a saving of about 25%.

India

When the first WHO malaria teams were sent to India, malaria control by modern methods was already being carried out in some parts of the subcontinent. A large-scale campaign was under way in the State of Bombay, and WHO sometimes sent malaria personnel assigned to South-East Asia to Bombay to observe the project.

The Government of India, in 1948, requested UNICEF and WHO assistance in starting malaria-control schemes in other states. The request was granted, in the hope that demonstrations of the results of malaria control in rural areas of India might stimulate the various states to undertake, or to expand, the control of the disease in their territories.

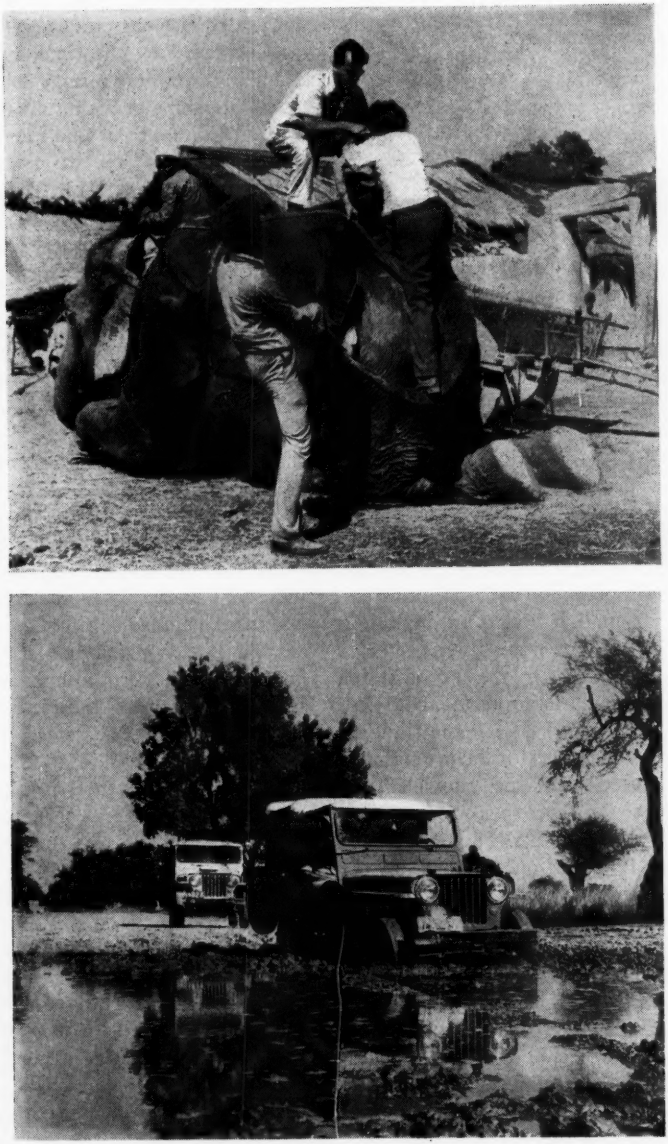
Four projects were set up, WHO assigning to each a team composed of a malariologist and a public health nurse, with the Government assigning a counterpart malariologist, an entomologist, one or more nurses or "lady health-visitors", malaria inspectors, and all the subordinate personnel. The projects were in four different states: Tarai, Uttar Pradesh, from April 1949 to February 1953; Jeypore Hills, Orissa, from May 1949 to May 1951; Malnad, Mysore, from May 1949 to April 1951; and Malabar, Madras,[2] from December 1949 to December 1951. All were located in areas of highly endemic malaria, transmitted by *A. fluviatilis*, either alone or in conjunction with *A. culicifacies*. Transmission lasted several months, if not the whole year. In some of the project areas, malaria was such an obstacle to development that no immigration was possible.

The results were generally very satisfactory. In some of the demonstration areas, it was found that one spraying a year was not sufficient, chiefly because the local population replastered the houses, thereby covering the DDT film on the walls during the malaria season. The people accepted the spraying operations willingly, and their extension to neighbouring villages was often demanded.

The number of persons protected in the four projects was as follows, the horizontal

[2] See Mara, L. (1954) *Bull. Wld Hlth Org.*, **11**, 679.

FIG. 15-16. MALARIA-CONTROL TEAM IN INDIA



These two photographs show the means of travel of WHO malaria-control personnel working in India

lines marking the end of WHO assistance in the form of personnel:

Year	*Tarai*	*Jeypore Hills*	*Malnad*	*Malabar*
1949	14 631	60 901	48 810	
1950	139 783	117 668	118 947	52 502
1951	149 954	113 000	*	115 553
1952	185 103	114 966	*	109 857
1953	151 618	*	*	125 870

* No data available

The respective state governments have continued the projects and expanded them through integration into a national malaria-control programme. Dr. Lakshmanan, Director-General of the Health Services of the Government of India, said, at the Seventh World Health Assembly, that the malaria work started by WHO in India had had so marked an effect that a national malaria campaign which aimed to protect 90 million people in 1954 had been inaugurated.

This national malaria-control programme actually began in 1953. Its target is to protect 125 million people in 1955-56, out of an estimated 200 million living in malarious areas. In 1952-53, the population protected had reached 30 million; by the end of March 1954, 63 million had been protected. UNICEF has contributed, and FOA is contributing, large amounts of supplies for the programme.

It is estimated that the equivalent of US $30 701 386 will be spent for malaria control in the period 1953-56, about two-thirds of the funds being supplied by the central government, with USA bilateral aid, and the remaining third by the states concerned. The various states have agreed to provide for a maintenance programme after the completion of the three-year plan. It was found during the 1953 campaign that the cost per person protected was equivalent to about US $0.10—the same amount as was required for the WHO/UNICEF project in the Jeypore Hills in 1950-51.

It is too early to assess the effects on public health, vital statistics, and socio-economic conditions that malaria control is gradually bringing about in India. However, the Tarai project, in which virtual control of malaria was achieved by the time the international team was withdrawn, may serve as an illustration of some of the results of malaria control. The infant parasite-rate dropped from 41.2% and 57.8% in two areas to 1.5% and 2.35%, respectively, after the introduction of control measures, which afforded direct protection to 185 000 people. The Tarai was a classic example of a very fertile region which could not be developed because of malaria, the transmission of which lasted throughout the year.[3] A few autochthonous inhabitants could escape the effects of the disease through immunity acquired in childhood, but immigrants were exposed to great danger. After the introduction of control measures in the area, colonization gained momentum, and 11 658 persons settled there. Food production was stepped up from 1 550 849 maunds in 1947-48 to 2 094 336 maunds in 1951. New industrial enterprises increased from 11 to 29, and these included new factories and a hydro-electric power plant. Several co-operative farms, with modern equipment, new roads, and a great increase in trade with neighbouring cities, were established. In brief, an unproductive, malaria-ridden valley was restored to intensive food production and to refugee settlement on a large scale.

Indonesia

As in India, the WHO expert team sent to Indonesia found there a number of localities already protected by a residual insecticide spraying programme.

The area selected for a WHO demonstration was in the southern part of Java, east of the port town of Tjilatjap. The Organization provided expert personnel for the project; the Government had great

[3] See Issaris, P. C., Rastogi, S. N. & Ramakrishna, V. (1953) *Bull. Wld Hlth Org.*, 9, 311.

difficulty in finding " opposite numbers " for the WHO team members, but, with USA bilateral assistance, it furnished all equipment and supplies.

A first survey took place from October 1951 to January 1952. It showed that, whereas malaria was highly endemic on the coast, even hyperendemic in some villages, the endemicity decreased farther away from the coast line. It was therefore decided to limit the project areas to a coastal band not wider than 15-20 km. The zone near Tjilatjap was to be the demonstration area; the zone on the eastern border of the demonstration area was to serve as the comparison area; and on the eastern border of the comparison area there was to be an " experimental " zone, which was to be sprayed in order to find out whether the control of this area would also control malaria in the hinterland, where endemicity was very mild even before control measures were undertaken.

Two anopheline species were found to be vectors : *A. sundaicus* and *A. subpictus*, of which the former was the more important. Great numbers of dissections were made ; *A. sundaicus* was found positive every month of the year, while *A. subpictus* was found with gland infection in February, May, and June. Transmission apparently occurs throughout the year, being highest after the start of the rainy season, from November to January (the dry season is from May to October).

The first spraying operations were carried out from 18 April to 17 June 1952 and protected 56 884 inhabitants. The spraying was restricted to the walls of houses up to a height of 2.5 m; kitchens and outdoor shelters were excluded. The houses in the rural areas generally had bamboo walls. In operations in October-November 1952, the whole walls of the houses, including those of kitchens and other structures, but excluding the roofs, were sprayed. Finally, in 1953, the roofs were also sprayed, leaving no internal surface unsprayed, so that the average sprayed surface per person was as much as 73 m². In all, 110 294 persons were protected.

The post-epidemic general malaria survey was carried out between May and July 1953. The results were as follows :

	Spleen-rate (%)	*Parasite-rate* (%)	*Infant parasite-rate* (%)
1. Demonstration area sprayed April-June 1952			
Pre-operational survey (Oct. 1951-Jan. 1952)	37.8	4.3	1.7
Post-epidemic survey (May-July 1953)	18.9	1.4	0.8
2. Check area not yet sprayed			
Pre-operational survey (Oct. 1951-Jan. 1952)	33.9	13.8	13.3
Post-epidemic survey (May-July 1953)	20	1.2	1.2
3. Experimental area sprayed Nov. 1952			
Pre-operational survey (Oct. 1951-Jan. 1952)	41.9	16.1	23.6
Post-epidemic survey (May-July 1953)	19.3	3.6	0

These results appeared rather unsatisfactory and confirmed the findings of the monthly infant parasite-rates, which had been regularly taken since September 1952. They were generally lower in sprayed areas than in unsprayed areas but showed that transmission was still continuing. Monthly morbidity surveys also indicated that fever cases were less numerous and parasitaemia less frequent in sprayed areas than in the comparison area; but still, falciparum fever cases did occur also in the sprayed area.

Entomologically, results were rather misleading at first : anophelines, *A. sundaicus* in particular, were very rare in sprayed houses, and more numerous in the unsprayed ones. During the last quarter of 1953, however, systematic hourly night captures showed that in the houses where no *sundaicus* could be found in the day-time it was quite easy to catch them at night, chiefly when biting human beings, and, in a much smaller pro-

portion, when resting on the walls. Unfortunately, trapping attempts failed, so that it is not known what happens to the *sundaicus* which do rest at night on the walls. But there seems to be an indication that *A. sundaicus* in that area has perhaps changed its behaviour after exposure to DDT. At the time, it was confirmed that transmission was continuing: during the last quarter, four new infections were found in infants in the sprayed area; and, during the next quarter, five new infections were discovered.

It is still too soon to be able to explain the relative failure of DDT in the Tjilatjap area, but the problem is being investigated. In the meantime, a new demonstration area has been selected in the Regency of Kedu, stretching about 70 km east of the eastern limits of the previous area. An initial survey was carried out in February-March 1954 and gave a crude spleen-rate of 87.4%.

Iraq

In August 1950, at the request of the Government of Iraq, a public health engineer trained in malariology was sent by WHO to assist in the supervision of emergency control operations against an impending malaria outbreak following floods. Later, in 1951, the Government requested aid in malaria control. An agreement was signed in February 1952, and a malaria-control demonstration was initiated.

WHO personnel arrived in Sulaimaniya, headquarters of the project, in July 1952. Surveying was immediately started and lasted eight months. It was found that the two vector species were those common in the eastern Mediterranean region—*A. sacharovi*, and *A. superpictus*. The latter hibernates completely; but the former, in spite of the cold winters of Kurdistan, seems to hibernate only partially. The Tanjero valley, which was roughly the area of the demonstration, was shown to be mesoendemic, with several localities, particularly south of Sulaimaniya, being decidedly hyperendemic.

Supplies, equipment, and transport were provided by WHO, from Technical Assistance funds, for the 1952 activities. In 1953, a large amount of material was furnished by UNICEF, so that it was possible to spray other " nahias " adjacent to the demonstration area as well as the demonstration area itself. Spraying operations started in April 1953 and continued until the end of August.

Since transmission in most districts begins not later than June, the protection of the area sprayed later in the summer could have been only partial. Thus, in the three districts that had been sprayed between April and June, spleen-rates dropped from 50%-60% to 15%-20%, whereas in the two districts where spraying was carried out in August, there was no appreciable reduction. Infant parasite-rates in October-November were 6% in sprayed areas (285 infants examined) as compared with 13% (146 examined) in the check area. The density of the two vector species in the area sprayed in the spring was practically zero, but they continued to be present in great numbers in the unsprayed areas.

Owing to various circumstances, the total population protected by spraying operations in 1953 amounted to only 23 000. A great expansion of the operations was planned for 1954. A new malariologist was assigned by WHO, and the national entomologist continued to assure entomological investigations. A closer relationship was established with the Institute of Endemic Diseases in Baghdad, which assigned a doctor to assist the WHO malariologist in the pre-operational survey, which started in 27 February and terminated before the end of June.

Spraying operations started in late March 1954 and were completed by mid-July; the houses of 209 000 people were sprayed. The average superficial area sprayed per person protected was 83 m^2 in 1953 and 74 m^2 in

1954. The cost of the operations per person protected was US $0.329 and $0.244 in 1953 and 1954, respectively.

Whereas in 1953 only DDT at the theoretical dosage of 2 g per m² had been employed, in 1954 several methods were followed, with DDT and with dieldrin, in an effort to find the most effective and most economical type of spraying for an eventual nation-wide campaign of malaria control, which would be the natural follow-up of the international assistance given by WHO and UNICEF.

It is envisaged that all the 3 million people of Iraq who are now exposed to malaria will be under protection in 1956.

Lebanon

Lebanon has a total population of 1.3 million, of which 135 000 reside in zones considered malarious. From surveys made in 1951-53, chiefly by WHO experts, malaria was found to be endemic in the coastal plains, along the river courses, and in the northern portion of the Bekaa, the large valley separating the Lebanon mountains from the Anti Lebanon range. The vector is *A. sacharovi*, alone or in conjunction with *A. superpictus*. Epidemic malaria, on the other hand, is characteristic of higher regions, where *A. superpictus* is probably the main vector.

A WHO malaria-control demonstration was carried out in Lebanon from July 1951 to the end of January 1954. The international personnel of the project consisted of a malariologist, an entomologist, a sanitarian, and a public health nurse, who was replaced after eight months by a national colleague. The Government, in February 1952, attached to the project a medical officer, the aforementioned public health nurse, and subordinate personnel; in March 1953, a sanitary engineer joined the national team. Equipment, supplies, and transport for the project, other than those provided by the Government, were furnished by WHO, through Technical Assistance funds. Later, in 1953, when the malaria-control programme was expanded into a nation-wide scheme, UNICEF supplied part of the insecticides required.

FIG. 17. MALARIA CONTROL IN LEBANON

Spraying the interior of a house with residual-action insecticide

The original demonstration area was divided between the Akkar and the Cazas of Hermil and Baalbek, and the check areas were established mostly across the Syrian border, in Syrian territory—a good example of inter-country co-operation in malaria control. Following the first year of activity of the project, the Government planned a nation-wide programme for 1953, with WHO personnel collaborating in the planning, in

the surveys, and in the operations, and supervising the assessment of results and the training of personnel.

There are probably at least three vector species in Lebanon: *A. sacharovi*, which was the only species found infected by the team, *A. superpictus*, and *A. claviger*. Apparently *A. sergenti*, *A. hyrcanus*, *A. algeriensis*, and *A. marteri*, though present, do not play a noticeable role, if any, in transmission.[4] The demonstration and check areas were surveyed five times in the course of the project, and practically the whole country was surveyed in preparation for the nation-wide programme.

Spraying operations in 1951, limited to the demonstration area, covered the houses of about 33 000 people; the following year, the population protected was practically the total population at risk—135 000, of which 102 784 were in the project area.

In April-June 1953, the control operations were carried out in different sectors by the Ministry of Health, the WHO team, the Karagheusian Foundation, and UNRWAPRNE.

The epidemiological study undertaken by the WHO team prompted the adoption of different measures of control: spraying all internal wall and ceiling surfaces with DDT at 2 g per m^2 either once or twice a year (the latter in the Akkar plains where the presence of indoor fires in the particular type of house would soon cover the DDT deposited with soot); or spraying with a particular method, studied already the previous year and consisting of alternating on the inside walls horizontal sprayed bands with similar bands left unsprayed; larval control of wells in the few sectors where *A. claviger* was present and was, on epidemiological evidence, the only vector; or larval control and residual spraying in areas where both *superpictus* and *claviger* were present. The technical efficiency of the spraying operations was remarkable: the superficial area treated per man-hour (per sprayman) was 311.8 m^2, and the provisional estimate of the cost per person protected gave the equivalent of US $0.17.

The system of "band spraying",[5] on which a preliminary report was presented to the Fifth International Congresses on Tropical Medicine and Malaria, was studied by the team. The results did not differ from those of areas where the whole of the inner surfaces had been sprayed. Still, an entirely satisfactory comparison of one method with the other could not be made for the same reasons which interfered with the final evaluation of the results of the various control measures adopted. These reasons were several: first, malaria endemicity was declining in Lebanon and in neighbouring territories during the period; secondly, the year 1952 was a year of particularly low transmission; thirdly, movements of population; and fourthly, previous use of DDT spraying in a number of villages of the demonstration area in Lebanon, and the domestic use of insecticides which altered the normal conditions of transmission in the check areas in the Syrian territory.

There is no doubt, in spite of the lack of reliable comparison areas (where malariometric rates dropped as well), that transmission was remarkably reduced during these two years, as illustrated below:

Surveys	*Demonstration area (Akkar, Hermil, Baalbek)*		*Comparison area (unsprayed)*	
	Spleen-rate	*Parasite-rate*	*Spleen-rate*	*Parasite-rate*
	(%)	(%)	(%)	(%)
First (pre-operational)	26.3	2.8	57.4	7.1
Second	13.7	0.17	33.8	2.2
Third	10.0	0.7	20.7	1.1
Fourth	8.4	0.18	17.8	1.05
Fifth (final)	4.5	0	18.9	0.78

Among the many valuable observations that the team made on the epidemiology and entomology of malaria in Lebanon was one

[4] See Gramiccia, G. (1953) *Rev. méd. Moyen-Orient*, 3, 293.

[5] Gramiccia, G., Garrett-Jones, C. & El Din Sultan, G. (1953) *Riv. Parassit.*, 14, 123

of the development of some degree of resistance on the part of *A. sacharovi* to DDT in two villages in 1953.[6]

Of the countries that extend from the shores of the Mediterranean eastwards to Iran, Lebanon has been the first to carry out, with international assistance, nation-wide malaria control. The campaign was continued in 1954, and it is hoped that it will be repeated in future years so that full eradication may be achieved. The training undertaken by WHO, through fellowships granted for the purpose and through the direct action of the WHO team, has also prepared the ground for the establishment of an adequate malaria service.

Pakistan

One of the earliest of the WHO malaria-control demonstrations was that in Pakistan. Operations started on 17 May 1949 and terminated on 31 January 1951. WHO provided three members for an international team: a malariologist, a public health engineer, and a public health nurse. The Government provided a senior entomologist, a second entomologist, two medical officers, and a sanitary engineer. UNICEF furnished equipment, transport, and supplies other than those which were the responsibility of the Government, which, as is usual in WHO projects, also paid for auxiliary personnel and other labour.

The headquarters of the project were in Gouripur, Mymensingh district, East Bengal. Surveys were made in June and December 1949, and in June-July and November-December 1950, both in the demonstration and in a comparison area. This project, like many others, in the course of the investigations modified pre-existing views on the epidemiology of malaria in the area. It was believed that transmission was limited to the second half of the year, but the team was able to establish that there is a pre-monsoon transmission, probably more significant than the post-monsoon transmission. (The S.W. monsoon starts about 10 June and lasts until September.) In other words, it might be concluded that, in the area in question, transmission lasts from the end of April to November.[7]

Of about sixteen species of anophelines present—some of which were very prevalent (*A. annularis*, *A. aconitus*, *A. barbirostris*, *A. philippinensis*, *A. hyrcanus*, and *A. vagus*)—only *A. philippinensis* was found infected, although about 2468 dissections were made of the other species also. *A. philippinensis* was the only species captured in greater numbers in bedrooms than in cowsheds. It was discovered that it breeds usually in dead rivers or marshes with submerged vegetation at about 1-2 m from the edges. There are two periods of high density breeding: April-July and October-mid-November. The species was found infected in May, which proves the pre-monsoon transmission. This finding, however, was made in 1950, which explains why operations in that year did not start when they would have if this knowledge had been available previously.

In 1949, the first spraying operations started only in July, owing to delay in arrival of supplies; they lasted until September. The spraying was at the rate of 2 g of DDT per m^2. More than 34 000 people were protected. In 1950, the operations started on 17 April and lasted until 25 August, obviously too late now that the pre-monsoon transmission was proved to exist. In this year, 231 916 persons were protected. The spraying was at the rate of 2 g per m^2, except in a few zones where 1.5 or 1.0 g were used. The villages already sprayed in 1949 were resprayed with either 1.0 g or even 0.5 g per m^2. This reduced dosage was motivated by the discovery that DDT (suspension) remained bio-

[6] Garrett-Jones, C. & Gramiccia, G. (1954) *Bull. Wld Hlth Org.* 11, 865

[7] See Quraishi, M. S., Ahmed, Mesbahuddin & Gramiccia, G. (1951) *Bull. Wld Hlth Org.*, 3, 673.

logically active on the walls (bamboo, sometimes plastered with mud) of the rural houses of the area for even more than one year.

The results were good; but they would probably have been better if spraying operations had terminated each year before mid-April, as was recommended in the final report on the project. In malariometric terms, the results are expressed as follows:

	Date of survey	*Number of children examined*	*Parasite-rate (%)*	*Spleen-rate (%)*
1. Area sprayed in 1949 and in 1950	June 1949	450	25	
		1559		69.5
	Nov.-Dec. 1950	1062	4.4	
		1050		7.8
2. Unsprayed check area	June-July 1950	903	22.7	
		835		68
	Nov.-Dec. 1950	770	14.6	
		769		66.9

No conclusions could be reached concerning the infant parasite-rates because the number of infants examined was too low. From 26.1% of 23 infants examined before spraying, the cumulative infant parasite-rates after spraying dropped to 5% of 223 examined in the sprayed area; but the infant parasite-rate was still 24% of the 217 examined in the unsprayed area.

From the entomological point of view, the results were satisfactory: not only did adults of the vector species practically disappear from the houses sprayed only a year before, but also the larval density was remarkably reduced in comparison with that of the unsprayed area, contrary to what was happening in the non-vector species, as shown below:

Larval density—average results per 100 dips, August-December 1950

	A. philippinensis	*Non-vector species*
Sprayed area	0.025	52.7
Unsprayed area	12.5	55

The annual cost per person for the spraying amounted to the equivalent of about US $0.165.

Besides malaria control and related work in environmental sanitation and in maternal and child health, the WHO team undertook, at the request of the Government, a survey and control scheme of kala-azar.[8]

Already in 1950 the East Pakistan Government, utilizing a surplus of the 1949 UNICEF allocation for malaria control, had extended the control work in the districts covered by the WHO project, thus protecting 84 351 persons. These control measures were carried out mostly by personnel trained by the WHO team. In 1951, the Government, with UNICEF aid, protected about a million persons, after termination of the WHO/UNICEF project. Progressive increase in the number of people to be protected was planned and, for the most part, has been achieved: in East Pakistan alone, more than 1.7 million people were protected in 1953, with the total for the whole of the country reaching 5.5 million. A country-wide programme of malaria control is still going forward, with considerable assistance from UNICEF.

Thailand

The population of Thailand is about 18.3 million, of which about 6 million live in malarious areas. A WHO malaria-control demonstration was carried out in Thailand between August 1949 and December 1951.

A WHO team consisting of a malariologist, an entomologist, a sanitarian, a public health nurse, and three laboratory technicians was sent to the country. UNICEF supplied equipment, transport, and insecticides. The Government attached to the project a malariologist, a malariologist-entomologist, an engineer (for one year), and laboratory personnel, sanitary inspectors, nurses, and all other essential workers. Further, the Government set up two national teams which, concurrently with the WHO demonstration and after having worked for some time on

[8] See *Chron. Wld Hlth Org.*, 1953, 7, 141.

the WHO-assisted project, assumed the responsibility for malaria control in sectors other than the demonstration area.

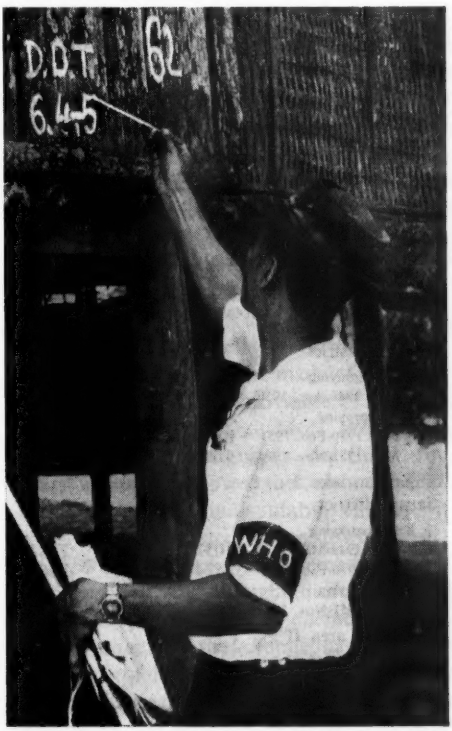
The demonstration area was the Sarapee district, and the comparison area for the first spraying operations was the adjoining Sansai district—both in Chieng Mai Province, northern Thailand. These areas were chosen on account of their high malaria endemicity, their density of population, and their agricultural importance. Irrigation made possible the production of two crops of rice a year, but malaria caused high morbidity during periods when labour was particularly needed for agricultural tasks. There was a general impression among the inhabitants that malaria had always been a serious problem in the foothills and that it spread to the plains with the introduction of canal irrigation.

The vector of the Chieng Mai Province had not previously been determined; but, early in the project, *A. minimus* was incriminated and was soon found with infected glands. During the 28 months of operation of the project, a total of 23 439 anophelines were dissected, of which 17 119 were *A. minimus*. This species only was found infected, with sporozoite-rates varying between 1.5% and 3.1%.

It was important to discover where *A. minimus* preferred to rest in houses. Resting places of more than 16 000 specimens were studied, and it was found that 92.7% had been captured indoors, most of them (about 86.7%) below a height of 2 m from the floor. Only 1.05% of all the *minimus* studied were captured under the " taitoon ", that is, the platform on which the raised wooden houses which are characteristic of the area are built. On the basis of these studies, spraying covered all wall surfaces, except those directly exposed to the outside, all the furniture parts, etc., which formed semi-permanent features indoors, mosquito nets, mats, and hanging objects in the rooms. When barns were used for human dwellings, they were also sprayed, as were cattle sheds and bath enclosures, when provided with walls. Experimentally it was found that the taitoons need not be sprayed, and they were omitted in the 1951 operations.

The first cycle of operations began in the spring of 1950 and had dramatic results. The second spraying cycle took place the following year, when the responsibility for the operational direction had already been transferred to the Thai medical officers, with WHO personnel serving only in an advisory capacity. All the data concerning the operations can be found in table I, page 70. The

FIG. 18. MALARIA CONTROL IN THAILAND



End of the spraying operations : writing the date of the spraying

results may be indicated, however, by the drop in the monthly infant parasite-rate. Of 3922 infants examined before the spraying, from September 1949 to March 1950, there were 29.04% positive; after the first spraying, of 1694 infants examined in the same period (i.e., September 1950 to March 1951), only 2.59% were found infected. The infant parasite-rate among all the infants born after the spraying, during a period of one year, totalling 2135, was only 0.47%, whereas in the comparison area the corresponding rate was 24%. After the second yearly spraying, which took place in April 1951, blood slides of 1598 infants were examined between May and November, and their aggregate parasite-rate was nil.

In November 1949, when the team started its work, the survey spleen-rate was 63.8% and the parasite-rate 47.3%; after the 1950 and 1951 sprayings, the rates, in November 1951, were 12.8% and 0.8%, respectively.

These dramatic results in malariometric indices were accompanied by more surprising entomological findings—i.e., a nearly total elimination of the vector species, as can be seen from the following data :

	Anophelines captured	*A. minimus captured*	*Man-hours employed*
Demonstration area : Serapee district			
Before spraying			
Aug. 1949-Apr. 1950	87320	9167	6911
After spraying			
May 1950-Feb. 1951	1864	—	6315
May 1951-Nov. 1951	4695	1*	3579
Comparison area I : Sansai district			
Before spraying			
Aug. 1949-May 1950	22057	5286	2885
May 1950-Feb. 1951	32524	5888	3688
After spraying			
May 1951-Nov. 1951	4992	1*	2454
Comparison area II : N. Maerim			
Unsprayed			
May 1951-Nov. 1951	9104	1507	1278

* These specimens were young, unfed ones captured near the periphery of the sprayed area. They were presumably hatched out from larvae drifted into the area. Both specimens were dead before arrival in the laboratory.

The monthly density of *A. minimus* larvae per 100 dips in the demonstration area was nil from May 1950 to March 1951, after the first spraying. After the second, it became positive (.004) in July, but was nil in all other months. The Sansai area also became negative after its first spraying (0.5 in May, nil from June to November 1951), whereas in the comparison area II, which was left unsprayed, the density per 100 dips was : May, 25; June, 5; July, 10.5; no data for August; September, 0.7; October, 1.33; and November, 4.

In 1951 Thailand began to receive substantial bilateral assistance from the USA, and the country was able to envisage a nation-wide malaria-control programme. A five-year plan was drawn up for the period 1953-57. Already in 1952, after the termination of the co-operative tripartite project, 1 541 288 people were protected; in 1953, 3 million were protected. In the latter year, Dr. Luang Ayurakit Kosol, Director of the Division of Malaria and Filariasis Control of Thailand, stated in his presidential address to the First Asian Malaria Conference, " WHO and UNICEF sowed the seeds, STEM [USA bilateral assistance] watered and fertilized those seeds, and thus malaria control [began] to bloom in Thailand."

The programme now being carried out by the Government, with bilateral assistance from the USA, provides for the protection of 4.5 million persons in 1954; and, within the following four years, all of the 6 million people in the malarious areas of the country should be under protection. After three years of spraying, each major area will be put under surveillance, and it is planned that in 1958 a programme of " protective surveillance " and incidental control operations will be instituted. At that time, the programme might be carried on without external assistance. It is estimated that the surveillance programme will cost the equivalent of about US $0.05 per person annually.

Viet Nam

The political conditions of Viet Nam did not offer many opportunities to carry out systematically the survey, operational, training, and evaluation work that characterizes most WHO malaria-control demonstrations. However, French malariologists had thoroughly studied the disease in many regions of Viet Nam, and so the first member of the WHO team to arrive, a sanitary engineer, was immediately entrusted by the Government with some spraying operations. This was in December 1950; the team malariologist arrived in April 1951.

WHO personnel undertook the technical supervision of malaria squads established in various regions of the country, such as the provinces of Gôcong, Biên Hoa, Thu Dau Mot, Tayninh, and the four provinces of the Pays montagnards du Sud—Banmethuot, Pleiku, Kontum, and Djiring-Dalat. Supplies, equipment, and transport were furnished by the Government, with bilateral assistance from the USA.

The activities of the team suffered because of a dearth of senior personnel; for many months, after the sanitary engineer had been transferred to another assignment, the WHO malariologist had no professional collaborator. Further, the Government was unable to provide a national malariologist until August 1952. No entomologist, either national or international, served on the project.

It can easily be realized how difficult it was to survey and to control a sector where military escort was necessary. Still, malariometric surveys were made of the province of Gôcong, which has severe seasonal malaria transmitted by *A. sundaicus*, and probably also by *A. subpictus*, and of the high plateaux of the Pays montagnards du Sud, where the WHO malariologist acted as technical adviser.

Spraying operations were carried out in many villages in the latter region, where the vector is *A. minimus* and, to a lesser extent, *A. jeyporiensis*. Although transmission appeared to be reduced, this reduction was less than would have been expected. The lack of an entomologist, the ever-present insecurity of the country, some inferior supplies of DDT, and, finally, the impossibility of keeping unsprayed comparison areas represented additional difficulties in carrying out and assessing the value of the operations. It was only in November 1952, when a WHO sanitarian arrived, that the malariologist could organize some observations by detaching him to the Pays montagnards du Sud area. No anophelines, adult or larvae, were captured in sprayed villages, though *A. minimus* was present in the unsprayed ones. Unfortunately, observations could not be continued, so no conclusions could be reached.

Malaria-control work was effected mainly in the province of Gôcong, where spraying with DDT (at the theoretical rate of 2 g per m^2) was carried out once a year, in October, before the transmission season. The population directly protected by the last spraying amounted to about 60 000. The spleen-rate, which was 33.5% in July 1951, was 7.7% in December 1952; and the parasite-rate had dropped during the same period from 19.1% to 5.1% among 2500 children examined, all from villages of the province.

No evaluation could be made of the spraying operations in the provinces of Tayninh, Biên Hoa, and Thu Dau Mot. With regard to the Pays montagnards du Sud,[9] four years' experience showed that, although DDT spraying had an indisputable efficacy, its action was manifested rather slowly in rural areas, where malaria was hyperendemic. For this reason it was thought useful to attack the parasites by means of chemotherapy as well as attacking the anopheline population by means of DDT. The method adopted in these experiments was the use of drugs for a short period of time, once every fortnight

[9] See Farinaud, M.-E. & Choumara, R. (1954) *Bull. Wld Hlth Org.*, 11, 793 .

TABLE I. SELECTED OPERATIONAL DATA ON SOME WHO-ASSISTED MALARIA-CONTROL PROJECTS, 1949-53

Country	Average superficial area treated per person protected (m^2)				Average superficial area treated per man-hour per spray-man (m^2)			Cost of DDT as per cent of total cost (%)					Cost per person protected per year (US $)			
	1st year	2nd year	3rd year	4th year	1st year	2nd year	3rd year	1949	1950	1951	1952	1953	1st year	2nd year	3rd year	4th year
India																
Tarai	60.9	50.6	39		119	174	230		55.0	58.5	40.0		0.22	0.19	0.16	
Jeypore Hills	15.3	19.7			139	215		45.5	56.0				0.10	0.10		
Malnad	30.6	31.6			205	206							0.12	0.12		
Malabar	29.5	31.9			155	204			31.6	27.5			0.17	0.16		
Pakistan	40.6	56.0			200	204		45.1	57.0				0.16	0.17		
Afghanistan	48.5	67.3	68	44	202	255	151	53.5	61.0	75.0			0.23	0.23	0.20	0.12
Thailand	31.6	22.0			145	160			53.3	64.5			0.13	0.10		
Iran	100.0	93.0	95	123								67.0			0.35	
Viet Nam	14.1	13.8			291											
Lebanon	37.0	39.7			209	312					51.8	52.7	0.16	0.17		
Cambodia	33.2	33.5			153	153				26.6	26.6		0.43			
Indonesia	32.7	73.0			175	305					66.0	84.1	0.12-0.19	0.25		
Burma	31.6	31.5			248	352					59.0	58.8	0.23	0.24		
Philippines	35.0	35.0			311	140					46.0	43.9	0.27	0.22	0.19	
Saudi Arabia													0.25			
China (Taiwan)	42.2	40.7			276	215					63.5	51.1	0.16	0.17		
Iraq	83.0	74.0			240	234						49.0	0.33	0.24		
Syria	74.0				177							46.9	0.31-0.35	0.35 *		

* Estimated

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for two months. Drugs were distributed only to children in the age-group 0-15 years and to pregnant women. Mepacrine was first used and was later replaced by chloroquine; other drugs, pyrimethamine and amodiaquine, were also used. This method, utilizing both treatment and prevention, gave interesting results and deserves consideration, together with DDT spraying, for the control of malaria in hyperendemic rural areas.

The project terminated in July 1953. After the departure of the WHO personnel, the Government planned to continue malaria-control activities, entrusting to specialized male nurses the surveys and the spraying operations, under the supervision of technicians supplied through USA bilateral assistance.

PILOT PROJECTS

Observations of the bionomics of some anopheline vector species have suggested that residual insecticide house-spraying methods might not control the transmission of malaria carried by them. This would be the case, for example, if the species fed and rested only outdoors, or even if it fed indoors but never rested upon the house walls. Determination of the habits of anophelines is difficult, however, for several reasons : entomological observations are generally made during the day, but it is known that many species of mosquitos go indoors at night and leave at dawn, or before; on the other hand, observations made at night are more difficult and less reliable, since the artificial light necessary for the work may alter the reactions of the mosquitos. Under these circumstances, the only way to make sure whether or not residual spraying would be effective against particular vector species is to try it.

It is for making experimental studies of the efficacy of spraying and other malaria-control techniques that pilot project teams are sometimes sent to particular countries. Pilot projects are also undertaken to determine the most effective and least expensive control methods under certain conditions.

FIG. 19. ENTOMOLOGICAL OBSERVATIONS

Searching for adult mosquitos indoors (India)

* Estimated

From the organizational standpoint, pilot project teams are very much like those used for demonstration projects. Their equipment is slightly more elaborate, however, to allow for further ecological observations.

Brief descriptions of some of the WHO malaria-control pilot projects follow.

Cameroons

When UNICEF's assistance was requested by the French Government for malaria control in the Cameroons, in Togo, and in French West Africa, it was realized that it would be advisable to undertake some operational research to determine the best and most economical insecticide to control malaria transmitted by *A. gambiae*—in addition to other species—in various zones of French West Africa and French Equatorial Africa. Accordingly, the Government undertook to carry out two pilot projects in Senegal and in the Upper Volta entirely with French personnel, but WHO aid was requested in the form of the services of a senior malariologist and a sanitarian for a pilot project in the Cameroons, the Government to supply another malariologist, an entomologist, and other necessary personnel.

The project was planned so that the pilot zone would lie within a much larger area which would also be protected by residual spraying, in the hope that the risk that persons from the experimental zone might be infected during night visits outside its borders might thereby be minimized. The headquarters was situated in Yaoundé. The town itself is protected by the Municipality, so that the project area can be described as an annular band about 35 km in radius around the territory of the capital, in a forest zone inhabited by about 40 000 persons.

The project started in April 1953; and the first survey was undertaken, with many difficulties, between 9 April and 24 August, during a dry period of the year. At that time, *A. gambiae* was found only infrequently; but, contrary to earlier reports, it could be captured in houses during the day-time, though apparently only in areas of high endemicity. It was discovered, with some surprise, that instead of there being a widespread hyper- or holo-endemicity, the endemicity of malaria varied greatly from place to place, spleen-rates in children ranging from 20% to 60%. The epidemiology of the infection appeared to be rather complex, some of the variability of transmission being due to differences in tribes and their living conditions. When the main rainy season started in September 1953, the correlation between indoor captures of *A. gambiae* and high spleen-rates was no longer observed. *A. gambiae* breeding increased greatly, and adults could be found in considerable numbers indoors.

In the meantime, the malaria entomological laboratory in Yaoundé began its work, and a few months later other new laboratories and office facilities were inaugurated, thereby greatly facilitating the observations.

Of the many species of anophelines present, sporozoites were found in the salivary glands of five: *A. gambiae*, *A. funestus*, *A. nili*, *A. moucheti*, and, once, *A. welcomei*. A new species, *A. (Neomyzoyia) rageaui* was found and described in all its stages by the French entomologist assigned to the project.

In order to study the main problem of the pilot project, five different treatments were planned, as follows:

1. BHC—0.2 g of the gamma isomer per m^2, two or three times a year,

2. Dieldrin—0.5 g per m^2, once a year,

3. DDT technical, —2 g per m^2, walls and roofs, once or twice a year according to needs,

4. DDT—2.2 g *p,p'* isomer per m^2, walls only, once or twice a year,

5. DDT—2 g per m^2, walls only, once or twice a year, according to needs.

FIG. 20. PILOT PROJECT IN THE FRENCH CAMEROONS

Mixing a dieldrin suspension in preparation for spraying

After a second pre-operational survey, which lasted from December 1953 to April 1954, and which showed an overall spleen-rate of 19%, a parasite-rate of 22%, and an infant parasite-rate of 16%, the first round of spraying operations started, actually beginning at the end of February 1954 and ending in May.

Liberia

In 1951, the Liberian Government requested assistance from UNICEF for malaria control. With WHO technical advice, a pilot project was planned, aimed at determining the most efficient and most economical method of malaria control in the forest area of Liberia, so that malaria control could eventually be expanded in the most rational way.

Since aid in yaws control had also been requested, it was found expedient to merge the two, so that the same laboratory building, the same general installations, and even the practice of house-to-house visiting could serve both projects. For the malaria control, WHO supplied a team composed of a malariologist, an entomologist, and a sanitarian. Their assignment started in March 1953, and the headquarters of the combined project was established at Kpain, a few miles from the frontier town of Ganta. The Government had, in the meantime, built houses and a laboratory. UNICEF furnished equipment and supplies.

The area was typical of the equatorial African forest. The population density was about 165 per square mile along the roads, but only 27.7 in the bush. The first general survey (April-July 1953) showed a spleen-rate of about 90% (median 91.6%) and a parasite-rate varying, according to locality, from 72% to 91% (median 82.5%). It was a holoendemic situation, in which both *A. gambiae* and *A. funestus* were found with infected glands.

More than 14 000 persons were protected by the first spraying operations, in May and June 1953. Three insecticides—DDT, BHC, and dieldrin—were applied to different sectors in different dosages and following different schemes. For instance, DDT was sprayed on walls and roofs in one sector, and only on the inside of the roofs in another.

The first post-operational survey, which was carried out between November 1953 and January 1954, gave indications that the spraying had reduced transmission. At about the same time, a pre-operational survey of an "expansion" area was undertaken, and the high endemicity of the country was confirmed. A spleen-rate of 84.2% was found in the 2-4-year age-group. The expansion area was then treated, bringing the number of inhabitants protected to 56 000.

Philippines

There were serious doubts as to whether or not malaria transmitted by *A. minimus flavirostris*, the vector most common in the Philippines, could be controlled by means of residual insecticides. WHO agreed, in 1952, to sponsor a pilot project to determine if residual spraying might prove an effective and economical means of malaria control. Accordingly, a team consisting of a malariologist and an entomologist, to whom the Government assigned, as opposite numbers, a malariologist and a medical entomologist, carried out a pilot project between February 1952 and June 1954. The Organization also contributed a small amount of supplies, through Technical Assistance funds, the rest being provided by the Government, with bilateral assistance. During the second year of operations, the WHO personnel acted only in an advisory capacity.

Headquarters of the project were in Pinamalayan, eastern Mindoro. The demonstration area in 1952 was situated south of this town, and the check area north of it. Pre-operational surveys showed high spleen- and parasite-rates in both areas, the former being 77% and 52.4% in the demonstration and in the check area, respectively, and the latter 43.4% and 34.2%; infant parasite-rates were 32.1% and 33.3%.

A. minimus flavirostris was the only vector in most of the area, and its bionomics were thoroughly studied. During the second year, a recently opened area in the foothill regions of the interior of the island, Merian, was surveyed. In this area, *A. mangyanus*, a species closely related to *A. minimus flavirostris*, was prevalent and was also an efficient carrier of malaria. Gland-infected specimens of *flavirostris* were found chiefly during the latter part of the year in Mindoro, but one gland infection was registered also in February. From the beginning of the entomological investigations, it was ascertained that this species rested indoors in the daytime in appreciable densities and was therefore not such a "wild" species as not to be amenable to control by DDT residual spraying. Further, it was found that most of the specimens indoors did not go higher than about 2.5 m from the floor. *A. mangyanus* was also found indoors during the daytime, but at lower heights, mostly below 1 m.

These findings gave hope that residual spraying might be effective even in Mindoro. Three sprayings were carried out, all with DDT at a theoretical dose of 2 g per m^2, once a year, using a 75% water dispersible powder.

The first spraying covered the demonstration area, lasting from 11 May to 14 June 1952 and protecting 25 177 people. The second spraying, directed by the national malariologist, lasted from 23 March to June 1953 and covered all the island, including the comparison area of 1952, with a total population of 143 079. The third spraying, in March-April 1954, protected 107 086 people; many families refused this cycle, for several reasons. The cost per person protected of the operations in 1954 amounted to the equivalent of about US $0.19.

The pilot project showed that malaria transmitted by *A. minimus flavirostris* in Mindoro could be controlled by one yearly application of DDT at the rate of 2 g per m^2. Among infants born after the second spraying, the parasite-rate was less than 1%, as

compared with rates above 20% in unsprayed areas. There are indications that infants found positive in the sprayed areas were living in houses left unsprayed. Further data, summarized below, confirmed the initial results.

In 1954, a field trial with dieldrin (250 and 500 mg per m²) was carried out, in Northern

TABLE II. RESULTS OF MALARIA-CONTROL PILOT PROJECT IN MINDORO, PHILIPPINES

A. Infant parasite-rates

Date of survey	Demonstration area		Comparison area	
	number examined	parasite-rate (%)	number examined	parasite-rate (%)
Pre-operational survey, April-May 1952	417	32.1	157	33.3
	First spraying		*Unsprayed*	
	Infants born after 14 June 1952			
December 1952	89	0	61	32.7
March 1953	192	1	162	24
June 1953	352	0	280	21.4
	Second spraying		*First spraying*	
	Infants born after spraying			
September 1953	359	0.6	60	0

B. Children, 2-9 years

Date of survey	Demonstration area				Comparison area			
	number examined	spleen-rate (%)	number examined	parasite-rate (%)	number examined	spleen-rate (%)	number examined	parasite-rate (%)
Pre-operational survey, April-May 1952	994	74.5	897	52.4	842	55	806	34.2
	First spraying				*Unsprayed*			
March-April 1952	902	28.3	885	5.3	864	57.4	840	27.4
	Second spraying				*First spraying*			
March 1954	921	17.3	926	4.5	1017	12.1	1051	3.1

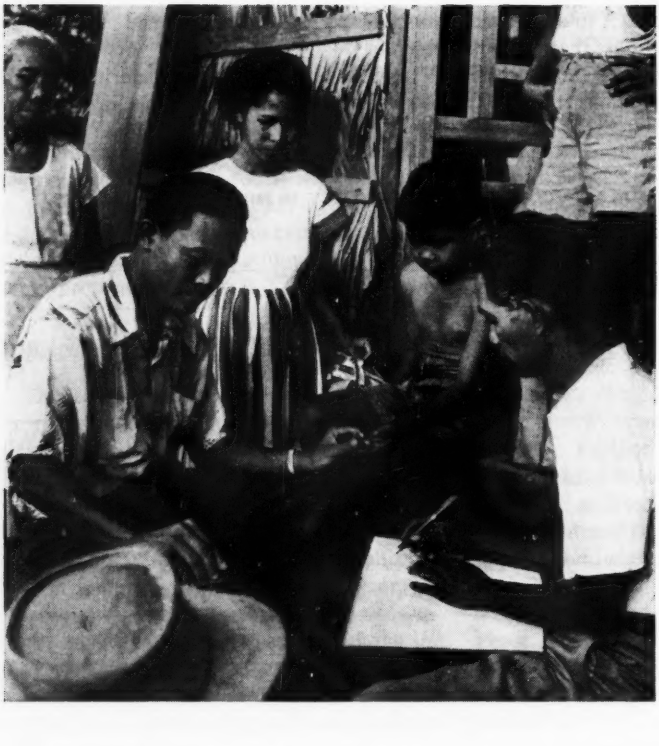


FIG. 21. PILOT PROJECT IN THE PHILIPPINES

Taking blood samples of children for determining parasite-rates

Luzon, according to the pattern of the Mindoro pilot project, by the Government Malaria Control Division, with personnel trained in the Mindoro project. By 4 July 1954, a total population of 30 577 had been protected in this experiment.

According to reports from the Philippines, the success of the WHO pilot demonstration led to the settlement of areas in Mindoro which had previously been considered dangerous on account of malaria. Malaria control on this island will be continued, along the lines proved effective in the Mindoro project, as part of a nation-wide programme in which the Government, with bilateral assistance from the USA, aims to protect all the population of the malarious areas of the country by the end of 1958.

Sarawak

As in the Philippines, a pilot project was undertaken in Sarawak to determine whether residual spraying could control malaria transmitted by a not too well known group of vector species—the *A. leucosphyrus* group. WHO supplied a malariologist and an entomologist for this project, though the latter was part of the team on a full-time basis only some time after the initiation of the work; the Government assigned a senior health inspector and auxiliary personnel to the project. In this instance, WHO also provided equipment and supplies, through Technical Assistance funds.

A first survey was made during the second half of 1952. It covered all the five " divi-

sions" of Sarawak and gave a general impression of the prevalence of malaria in the country. The demonstration area chosen was in the territory of the river Baram and its tributaries; the comparison area was in the basin of the river Tinjar. On the upper reaches of the Baram, spleen-rates as high as 88% and parasite-rates of 50% were found. The distance of the demonstration and check areas from Kuching led the senior adviser to move his headquarters to Marudi, in the Baram district.

A. leucosphyrus and *A. barbirostris* were the only species found with infected glands. *A. letifer* was also found with sporozoites, but as the area in which they were found infected was not really malarious, it was suspected that the infection was not human. The Malaria Reference Laboratory in England later confirmed that the sporozoites were of non-human malaria.

The first spraying operations were carried out in February-March 1953, partly with DDT (Upper Baram) and partly with BHC (Lower Baram). DDT spraying was to be repeated every six months, BHC every three months. The theoretical dose of DDT was 2 g per m^2, that of BHC, 0.10 of gamma isomer. The second DDT and the third BHC sprayings were carried out in August-September 1953. In April 1954, the third DDT and the fifth BHC sprayings were started. In all, 31 villages, with a total of about 6500 inhabitants, were sprayed in the demonstration area.

This project is the only one in which motor vehicles have not been used: all movements have been made by canoes with outboard motors, or on foot. In addition, because of the distances and the difficulties of communications, it has been found more convenient to parachute supplies and insecticides rather than to transport them by surface.

Preliminary data from this project would seem to indicate that malaria carried by *A. leucosphyrus* and *A. barbirostris* in Sarawak can be controlled by residual insecticides.

MALARIA-CONTROL ADVISORY TEAMS

Advisory teams are sent to a country, upon the request of the government, to assist in planning a malaria-control scheme, in raising the technical level of the operations and of their assessment, in training personnel, and in establishing an organization for malaria control to take care of future developments. A large part of the assistance that such a team may give to a government is in surveying the whole country and in defining its malaria epidemiology. Often, a malaria-control demonstration team, after one or two years' activity, acquires the status of an advisory team.

A malaria-control project in Iran may serve as an example of the work of an advisory team.

Iran

In 1950, by agreement with the Government of Iran, WHO assigned a team composed of a malariologist, an entomologist, and a public health engineer to advise and guide the relevant bodies of the Government on (1) the establishment of a permanent antimalaria organization, (2) the development of a national malaria-control programme and its practical application, and (3) the establishment of a national training programme for technical and auxiliary personnel.

The international personnel started their work in Iran in April 1950 and remained there until June 1953. Co-operating with Iranian malariologists and entomologists, they assisted in clarifying the epidemiology of malaria in the country and in determining the distribution of anopheline species. During the period of the work of the team in Iran, the Government progressively expanded its

residual spraying campaign. A malaria-control organization developed, and an institute of malariology was eventually established by the Ministry of Health and the University of Teheran. This institute was responsible for the general epidemiological and entomological survey of the country, for the planning of the control campaign, for the assessment of the results, and for training programmes, whereas the active implementation of the campaign was entrusted to a co-operative public health organization (a joint enterprise of the Government and USA bilateral assistance), largely decentralized at the provincial level.

The national campaign is large in scope: in 1953, for example, 14 542 villages were sprayed, affording protection to a population of 4 243 938. Although it is still in progress, the work has already reduced morbidity from malaria, with consequent improvements in social and economic conditions.

WHO OBJECTIVES IN MALARIA CONTROL

1. To promote the eradication of malaria as a public health problem from the world ;

2. To assist governments in establishing or strengthening their malaria services and in developing their national programmes of malaria control in the light of available scientific knowledge ;

3. To stimulate and co-ordinate research in the fields of malariology and malaria control ;

4. To promote and facilitate the exchange of technical information.

INTERNATIONAL EXCHANGE OF TECHNICAL INFORMATION

The exchange of technical information serves all countries and is one of the major functions of WHO. It is accomplished by several means: expert committees, symposia and conferences, consultant aid, fellowships and other professional training activities, and documentation.

In malaria control the Organization aims to promote extensive use of the new methods and to put information on the latest developments at the disposal of health administrations and health workers concerned with this problem. As an international health agency in touch with malariologists and with malaria field activities in all parts of the world, WHO can make available the authoritative advice of malaria experts from different countries and can act as an international clearing-house for information which might not be easily accessible through other channels.

EXPERT COMMITTEES AND ADVISORY PANELS

To give technical authority to its advice to governments and to aid in formulating its own programmes, WHO calls upon experts from all countries. The Director-General appoints an expert advisory panel on a particular subject, such as malaria, paying attention to the geographical representation as well as to the technical competence of the individuals chosen.

From the relevant advisory panel are selected the members of expert committees, which are convened to discuss specific aspects of certain health problems. The choice of members of an expert committee depends upon the topics to be considered. This system of drawing the committee from a larger technical group, the expert advisory panel, makes possible a flexibility of membership and is a further guarantee of the technical competence and of the international character of the committee. The reports of the expert committees are a guide for health administrations and provide the technical basis for WHO's activities with regard to the subject in question.

The Expert Committee on Malaria was the first WHO technical committee to meet in Geneva, its initial session being held in April 1947. It formed a link with the Malaria Commission of the former League of Nations; but it had at its disposal weapons which the Commission did not possess—residual insecticides and new drugs.

In its first report,[10] the committee spoke of country-wide malaria-control programmes by DDT house-spraying, thus advocating the practicability of control on a scale which would have been inconceivable a few years earlier. While singling out as the method of choice for malaria control the destruction of the mosquito vector in its adult stage, indoors, by means of spraying with residual-action insecticide, the committee nevertheless recognized that tactics had to be adapted to the conditions of each locality.

The Malaria Commission of the League of Nations had knowledge of two antimalarials in addition to quinine—pamaquine (then called plasmoquine) and mepacrine (then known as Atebrin). But the Expert Committee on Malaria, from its early meetings, has had for consideration a number of drugs which have been developed since League of Nations days—proguanil, chloroquine, amodiaquine, and pentaquine and isopentaquine, to which two other important antimalarials,

[10] *Off. Rec. Wld Hlth Org.*, **8**, 8

pyrimethamine and primaquine, have been added in the past five years.

In spite of the enormous value that the committee recognizes in some of the new drugs, its repeated opinion has been that, except during epidemics, in routine malaria control, they do not play a primary role. Collective chemoprophylaxis can be recommended only in particular circumstances, such as for aggregations of labour living under conditions in which an effective attack on transmission is not feasible or has not yet been undertaken; for mobile groups in malarious territories; for certain easily supervised social groups, such as schoolchildren, living in endemic areas where control measures are not yet in operation; and for armies in the field.

In its fifth report,[11] the committee expressed certain views concerning the use of antimalarial drugs: first, that some of them (proguanil and pyrimethamine) should be limited to suppressive use and not be employed for treatment, at least of acute malaria in nonimmunes; secondly, that synthesized antimalarials may play an important part not only during malaria epidemics, but also in malaria-control campaigns in areas where the application of antimosquito measures is impossible or likely to be unsatisfactory because of the behaviour of the local vector, movements of the population, or other factors; finally, that radical cure of malaria cases, which is now generally possible, should be considered an essential measure for limiting the extension of the disease when the vector-control campaign has been interrupted and new cases arise, owing to relapses or immigration of infected individuals.

The place of antilarval measures has also been specified by the committee. In general, such measures are too costly to be justified where spraying with residual insecticide to kill the adult vectors can effectively control malaria. There are, however, certain circumstances in which antilarval measures are preferable or necessary, for example, in concentrations of population and urban zones, where larval control is usually more economical; in rural areas where the local vector breeds in only a few and easily identifiable and accessible places (this is true, for example, of *Anopheles maculipennis* in Dalmatia, *A. claviger* in Lebanon, and *A. pseudopunctipennis* in Mexico), making the treatment of these places less expensive than spraying all the houses; and, finally, in places where residual spraying does not give the results one might expect, as in localities where people sleep outdoors during the transmission season and where the local vectors generally bite men and rest outdoors.

When larval control is indicated, it is not advisable to use the same insecticide, or a nearly related one, as is used for residual spraying, in view of the danger of vectors' developing resistance to the latter.[12]

In summary, the committee concluded at its last session that:

" . . . despite the great success of the newer forms of insecticidal work, there still remains room for the use of the more traditional methods, such as antimalarial drugs, prevention of breeding and especially of the creation of man-made breeding-grounds, and the fostering of changes in the practice of agriculture and animal husbandry, and in social conditions, which have by themselves eliminated malaria from large territories in Europe and America." [13]

When residual insecticides were first declared the weapon of choice for malaria control, very little was known about them. Producers and purchasers of insecticides, and of equipment for applying them, needed technical guidance. It was to help meet this need that WHO, on the suggestion of the Expert Committee on Malaria, in 1948 convened an Expert Committee on Insecticides, among whose principal tasks was " to specify international standards for insecticides and their formulation, to stimulate the development of

[11] *Wld Hlth Org. techn. Rep. Ser.*, 1954, 80

[12] See *Chron. Wld Hlth Org.*, 1954, 8, 131.

[13] *Wld Hlth Org. techn. Rep. Ser.*, 1954, 80, 24

standard spraying-equipment on a regional basis, and to deal with all other questions relating to the proper use of insecticides ".[14]

This committee has drawn up specifications intended to guide both consumers and manufacturers of insecticides and spraying equipment. In 1953, these specifications were published under the title *Insecticides: manual of specifications for insecticides and for spraying and dusting apparatus.* The committee is continuing to make additions and amendments to the specifications contained in this manual, which, because of its loose-leaf form, can be kept up to date.

CONFERENCES AND SYMPOSIA

Conferences and symposia are another means of bringing together experts on a particular subject for an exchange of views and for pooling knowledge and experience. WHO-sponsored conferences are often of regional interest, designed to obtain corporate and authoritative advice on problems of a regional nature.

One such problem with regard to malaria, and an extremely important problem, is the control of malaria in Africa south of the Sahara, transmitted by *A. gambiae*. Until recently, almost nothing had been done about malaria in tropical, rural Africa, where the disease is practically ubiquitous. There were several reasons for this seeming inertia, the principal ones being differences of opinion as to the advisability of controlling malaria in a population which, in adulthood, did not appear to suffer greatly from the infection owing to immunity obtained in childhood; and the conflicting results of the first trials of residual insecticides in the control of malaria carried by *A. gambiae*.

To aid in the clarification of these two problems, WHO, in collaboration with the Commission for Technical Co-operation in Africa South of the Sahara, organized the Malaria Conference in Equatorial Africa, held in Kampala, Uganda, in 1950. This conference gave partisans of different viewpoints an opportunity to meet and discuss what should be done about malaria in Equatorial Africa. They reached the unanimous opinion that " whatever the original degree of endemicity, malaria should be controlled by modern methods, as soon as feasible and without awaiting the outcome of further experiments ".[15] With regard to methods of control, the conference participants indicated the insecticidal techniques which they believed could be expected to reduce transmission of malaria even in *A. gambiae* areas. The conference, in effect, stimulated the initiation of malaria control in rural Africa and provided technical guidance as to the best procedures to be followed.

A question of general interest in malaria control is how to achieve a satisfactory co-ordination in time and space of large-scale programmes within a country and between adjoining countries, with the aim of eliminating malaria from vast areas and thereby enabling the interested countries eventually to discontinue residual insecticide campaigns. This was the main subject discussed at the First Asian Malaria Conference, held under the auspices of WHO in Bangkok, Thailand, in September 1953.[16] One of the particularly significant recommendations made at this conference was that " in planning malaria-control programmes, the principle of merging the areas of control both within and outside the borders of the countries concerned, on an inter-country, intra-regional, and inter-regional plane be followed ".

A third conference on malaria, the Second Asian Malaria Conference, actually concerned two Regions: the Western Pacific, and South-East Asia. This conference, which met from 15 to 24 November 1954 in Baguio, the Philippines, emphasized the necessity of planning malaria control so that the disease

[14] *Off. Rec. Wld Hlth Org.*, 11, 58

[15] *Wld Hlth Org. techn. Rep. Ser.*, 1951, 38, 46

[16] See *Chron. Wld Hlth Org.*, 1954, 8, 117.

could be eradicated, and the residual-insecticide house-spraying discontinued, in as short a time as possible, before the vector may develop resistance to the insecticide used. The participants reviewed the situation with regard to the prevalence of malaria in the two Regions and to efforts under way to control it, and pointed out that effective control was feasible for comparatively little financial investment.

A symposium of great interest to workers in malaria was sponsored by the WHO Regional Office for Europe and the Istituto Superiore di Sanità—the First International Symposium on Control of Insect Vectors of Disease, held in Rome in October 1953.[17] At this symposium it was generally agreed that the principal method of controlling insect vectors of disease is the use of insecticides, and that the most difficult problem is the development of resistance to insecticides.

It was emphasized that detailed study of insect physiology and biochemistry and free research are required, and that there is no time to spare. The symposium participants suggested the different lines of research which should be immediately pursued and the type of international action and co-operation which would be most useful.

CONSULTANT AID

A direct form of exchange of technical information is the advice given to health administrations, upon request, by experts from other countries. WHO aid of this type in malaria control is illustrated in fig. 22.

In some instances the experts in question are WHO headquarters or regional office staff members; in others, they are consultants recruited for assignments of varying lengths for specific purposes. A consultant may go to a country to aid in planning a malaria-control scheme (Professor A. Missiroli, to Bulgaria and Hungary, 1949); to lecture in universities or other institutes on modern methods of malaria control (Professor J. M. Henderson, to India and Thailand, 1949; Dr. A. Gabaldón, to India, Dr. M. F. Boyd, to Venezuela, and Professor M. E. Shortt, to the USA, all in 1950; Professor P. C. C. Garnham, to Portugal, 1951 and 1952, and Professor G. Raffaele, to Portugal, 1952; Sir Gordon Covell, Dr. P. F. Russell, and Mr. M. H. Holstein, to Nigeria, 1952); to give advice on special questions, such as whether, for a given territory, vector-species eradication might be preferable to a simple malaria-control programme (Dr. D. Bruce Wilson, to Ceylon, 1950); or to make a general survey of malaria prevalence and malaria control in a continent (Professor F. J. C. Cambournac, Africa, 1950), or in particular countries (Dr. G. Giglioli, to Mexico, 1949, and to Nigeria and the Gold Coast, 1952).

TRAINING OF PERSONNEL

A dearth of professional personnel is one of the principal difficulties facing many countries which want to undertake malaria control. Since training facilities and the funds necessary for training activities are in many instances also lacking, governments request international assistance in building up a corps of trained workers for malaria-control organizations and operations.

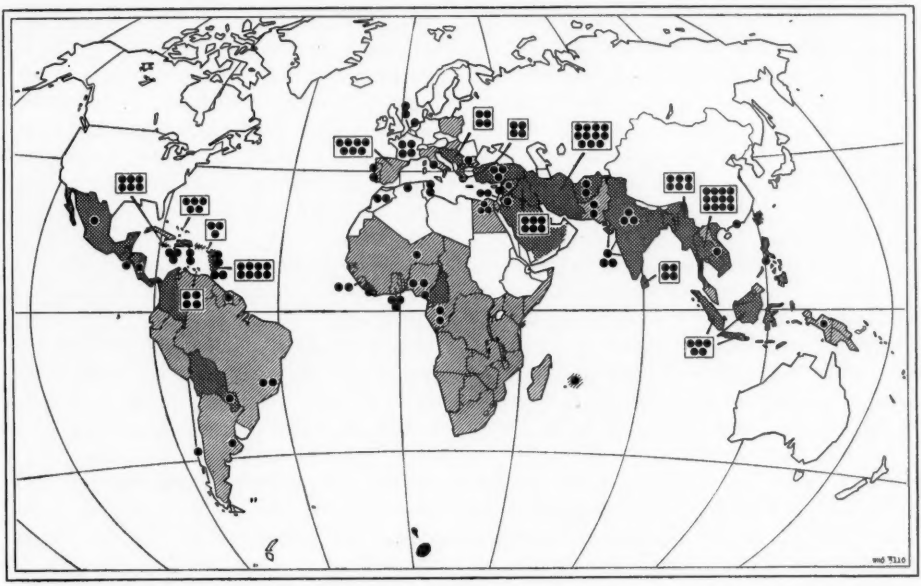
WHO helps to train personnel for malaria control by sponsoring courses, awarding fellowships, and providing in-service training in connexion with field projects. In addition, the Organization aids institutes of malariology by furnishing teaching equipment or providing the services of lecturers from other countries.

Courses in malariology

WHO-sponsored courses in malariology are a means by which instruction may be

[17] See *Chron. Wld Hlth Org.*, 1954, **8**, 129. The papers presented at this symposium have been published and are available through the Fondazione Emanuele Paternò, Viale Regina Elena, 299, Rome. The papers are in either French or English, with summaries in these two languages and in German and Italian.

FIG. 22. WHO ASSISTANCE IN MALARIA CONTROL, 1947-53: FELLOWSHIPS, CONSULTANT AID, TEAMS



● *Fellowships for study of malaria control and entomology*
Countries visited by WHO malaria experts
Countries which received the technical assistance of WHO teams in carrying out antimalaria work

given to professional personnel from countries which, in general, do not have facilities for specialized training in malaria control. Four such courses have been held: one in Rome, in 1949, in collaboration with the Istituto di Malariologia E. Marchiafava and the Istituto Superiore di Sanità; two in Portugal, in Lisbon and Aguas de Moura in 1951 and again in 1952; and a fourth in Lagos, Nigeria, in 1952. A fifth course is now in progress in Yaoundé, the Cameroons. All except the course in Lagos were given in French.

With the co-operation of a malaria institute or the malaria services of a country, a course of two to three months' intensive training in malaria control is arranged. WHO invites authorities of international standing to give lectures, in addition to those given by the regular staff of the institute or malaria organization and by other specialists from the host country, and grants fellowships so that government-selected Fellows from a number of countries may attend. The enrolment averages twelve persons—doctors, entomologists, and sometimes other professional personnel concerned with malaria control. To date, 38 fellows have received training in WHO-sponsored courses.

All aspects of malariology are dealt with as fully as the allotted time permits, and practical work is combined with lectures and demonstrations. At the course in Lagos, for example, lectures accounted for 96 hours; practical work, 91 hours; and demonstrations, film shows, discussions, and seminars, 45 hours. At the conclusion of the course, an examination is given, and those who successfully pass it are awarded a certificate.

Fellowships

The granting of fellowships is one of the most widely used types of assistance which WHO gives governments in strengthening their health services. It is a valuable means of exchanging technical information, since the fellow can pass on to others the knowledge which he has gained abroad or in special, internationally sponsored courses offered in his country.

In addition to awarding fellowships to participants in WHO-sponsored courses in malariology, the Organization grants fellowships to government-selected professional personnel to attend the regular training courses held in malaria institutes in many countries—e.g., India, Italy, Pakistan, Portugal, and Venezuela.

In all, up to the end of 1953, 157 fellowships were utilized by medical graduates, entomologists, or engineers, from 58 countries, for studies in malaria control (see fig. 22).

In-service training

In-service training, given in conjunction with field operations in malaria control, is a practical approach to the problem of preparing personnel for malaria-control services. Such training is given by all WHO field teams. National "opposite numbers" of international team members are prepared to take over the work and to train other national personnel.

Unlike regular training courses and fellowships, in-service training is not restricted to professional personnel but also reaches sanitary inspectors, field assistants and foremen, laboratory assistants, and insect collectors. It aims to form in the country a nucleus of people adequately trained, at all levels, for a malaria-control organization.

Data from a survey of the training activities carried out in the various WHO projects up to the end of 1953 are summarized below.

NATIONAL PERSONNEL TRAINED IN WHO MALARIA-CONTROL PROJECTS, 1949-53 *

Medical officers who received training, as national counterparts to WHO team members, in malariology	30
Scientists who received training, as national counterparts to WHO team members, in entomology	10
Public health engineers/sanitarians who received training, as counterparts to WHO team members, in malaria control	11
Medical officers who received training, as trainees, in malariology	216
Scientists who received training, as trainees, in entomology	16
Public health engineers/sanitarians who received training, as trainees, in malaria control	19
National project personnel who received training in field work	265
National project personnel who received training in laboratory work	179
National trainees who received training in field work	544
National trainees who received training in laboratory work	87
TOTAL	1 377

* Including in-service training

CO-ORDINATION OF RESEARCH

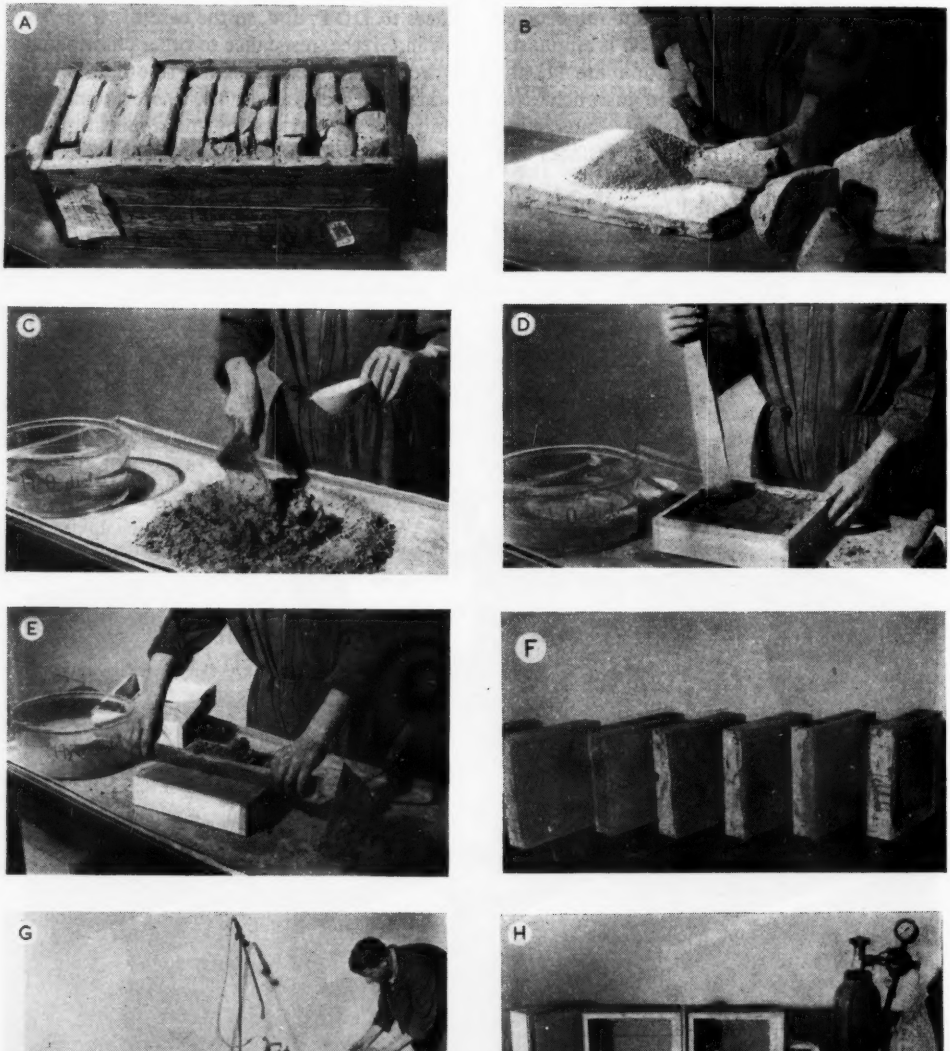
Two problems of paramount importance for malaria control which WHO is emphasizing as subjects of investigation are (1) the development of resistance to insecticides in vector species, and (2) the interaction between certain absorbent wall surfaces and insecticides.

As has been indicated (page 43), and as will be discussed further in another section (page 90), at least two vector species are known to have become resistant in some places to DDT; and, in the case of *A. sacharovi* in Greece, resistance to other chlorinated hydrocarbon insecticides has also developed. It therefore seems advisable, wherever malaria control is carried out by the application of insecticides, to make observations on the possible decrease in susceptibility of the local anopheline vector species to the insecticides being used. Such observations

FIG. 23. FIELD TESTING OF ANOPHELINE SUSCEPTIBILITY TO INSECTICIDES

Standard field testing kit for determining the susceptibility of the local anopheline vector species to the insecticides being used. Anopheles are put in contact with filter paper impregnated with standardized DDT solution in oil. Thirty-four of these outfits are in use in different parts of the world, aiding in the study of the behaviour of anopheline populations in relation to their possible resistance to insecticides, the mechanism of which is not yet being investigated by specialized laboratories.

FIG. 24. TESTING ACTION OF INSECTICIDE ON SAMPLES OF EARTH USED AS BUILDING MATERIAL



(All photographs published by courtesy of the Istituto Superiore di Sanità, Rome)

can be made in the field and, with more precision, in specialized laboratories.

For field observations, WHO has developed a testing outfit (fig. 23) which is distributed to entomologists working with WHO teams and to many other entomologists in national malaria-control services. This outfit, based on the method suggested by Busvine & Nash,[18] is used for determining LD_{50} on mosquitos kept for a given time in a container lined with filter paper impregnated with a given oil solution of DDT or other insecticide.

For more precise determination of the susceptibility of vector species to insecticides, WHO has enlisted the co-operation of the London School of Hygiene and Tropical Medicine and the Istituto Superiore di Sanità, Rome. Eggs of vector species are sent to either of these institutes, where attempts are made to obtain and maintain a colony of adults which may subsequently be utilized for testing susceptibility to given insecticides, by the Busvine & Nash technique or by other methods. Thus far it has proved difficult to transport the eggs rapidly enough to obtain sufficient adults to start a colony.

The second problem, the interaction between walls and insecticides sprayed on them, is important in many malarious areas of the world. Bordas, Downs & Navarro [19] found that in Mexico the activity of DDT on adobe walls varied considerably : while on certain types of adobe the DDT remained effective for more than three years, on other types it lost its efficacy within three months. More recently, other investigators [20] (A. B. Hadaway & F. Barlow—personal communication, 1954) have found that this inactivation of DDT on certain types of mud is due to its adsorption, to its penetration into the depth of the mud walls. A correlation has been suggested between the iron oxide content of the mud and the speed of such adsorption.

Accurate study of building materials of this sort is needed to determine which insecticides should be used for malaria control in certain areas. To this end WHO has initiated a co-ordinated testing programme of earth used for building houses or huts. With the assistance of some of the members of the Expert Advisory Panels on Malaria and on Insecticides, a technique for the uniform performance of tests has been proposed (see fig. 24), and several institutes have agreed to carry them out. Collaborating in this research are the Institut Pasteur, Paris; the Istituto Superiore di Sanità, Rome; Geigy Laboratories, Basle; Malaria Institute of India, Delhi; Divisiòn de Malariologia, Maracay; Communicable Disease Center, Savannah; and the Serviço Nacional de Malaria, Rio de Janeiro. Samples from most of the WHO-assisted projects have been sent to one or another of these laboratories, and investigations are under way.

It is hoped that, on the basis of very recent observations made by F. Barlow (personal

[18] See *Wld Hlth Org. techn. Rep. Ser.*, 1954, **80**, 30.

[19] Bordas, E., Downs, W. G. & Navarro, L. (1951) *Science*, **114**, 259; and Bordas, E., Downs, W. G. & Navarro, L. (1953) *Bull. Wld Hlth Org.*, **9**, 39

[20] Hadaway, A. B. & Barlow, F. (1951) *Nature (Lond.)*, **167**, 854; Barlow, F. & Hadaway, A. B., *Bull. ent. Res.*, 1951, **41**, 603; 1952, **42**, 769, **43**, 91, 281; 1953, **44**, 255

Explanation of fig. 24

A — Unbaked mud bricks sent by one of the WHO teams for testing at the Istituto Superiore di Sanità

B — Breaking up the mud specimens

C — Making a paste of fragments with distilled water

D — Filling specially made forms with the mud paste

E — Smoothing the surfaces of the newly made bricks

F — Mud bricks ready for spraying, to be used as the back wall of testing cages

G — Spraying of the prepared mud bricks. The speed of the conveyor belt and the delivery rate of the nozzle are calculated to give a precise amount of insecticide per unit of surface

H — Biological testing of mosquitos in shallow cages in which they are confined between a glass wall and the sprayed back wall. At the right is a CO_2 tank, the CO_2 being used for stunning the mosquitos before transferring them to the observation cages

communication, 1954) and by M. A. Alessandrini (personal communication, 1954), "impression preparations" of the surface of walls may be achieved on adhesive material which could subsequently be analysed in a reference laboratory for its content of insecticide. This procedure would eliminate the necessity for carrying out complicated chemical, physical, and biological tests on bulky material, such as portions of walls or bricks prepared from earth shipped from remote areas.

While these two problems are the chief subjects of WHO investigations relative to malaria control, others of considerable practical significance are part of the operational research carried out by field teams engaged in malaria control. Such research—on epidemiology, entomology, and techniques of control and their evaluation—is made possible by the varied composition of the teams and by the uniform pattern of their observations, as has been suggested in the section describing WHO-assisted malaria-control demonstrations.

TECHNICAL DOCUMENTATION

Publications and documents are one of the principal channels for exchange of technical information and are a form of assistance which reaches all countries. WHO publications are concerned particularly with subjects related to the Organization's work and considered of international health significance.

In the *Bulletin of the World Health Organization*, which is the main scientific periodical of WHO, are published the results of specific disease-control methods, studies of the geographical distribution of diseases, surveys on specific subjects made by expert consultants on behalf of WHO, original findings made in the course of WHO field programmes, laboratory studies on subjects of interest to the Organization, and reviews of the literature on subjects relevant to the work of WHO. A recent number of the *Bulletin* is devoted solely to malaria control.[21]

In the *Technical Report Series* appear the reports of expert committees and other expert groups and the reports on some of the conferences held under WHO auspices. Three reports of the Expert Committee on Malaria and four of the Expert Committee on Insecticides and the report on the Malaria Conference in Equatorial Africa have been published in the *Technical Report Series.*

The *World Health Organization: Monograph Series* contains studies of wide interest and lasting value, each monograph being on one particular subject and, in most cases, representing the views of one author. Some, however, are a collection of papers on a certain topic by a number of contributors. There are several monographs on malaria.

Lutte antipaludique par les insecticides à action rémanente [22] was the first report on large-scale campaigns against malaria through the use of residual insecticides. It is a carefully documented study of campaigns in about twenty countries in four continents.

A second monograph, *Biology of Anopheles gambiae*,[23] is the result of research carried out in French West Africa on the principal vector of malaria in Africa. It is an important and highly specialized study of a vector which was responsible for severe epidemic malaria in Brazil, where it was eventually eradicated. Annexes give details of the geographical distribution of *A. gambiae* in Africa, a table of sporozoite-rates for certain regions, and a key to the identification of the common anopheles in French West Africa.

[21] *Bull. Wld Hlth Org.*, 1954, 11, No. 4-5

[22] Pampana, E. J. (1951) *Lutte antipaludique par les insecticides à action rémanente*, Geneva (*World Health Organization: Monograph Series* No. 3)

[23] Holstein, M. H. (1954) *Biology of Anopheles gambiae; research in French West Africa*, Geneva (*World Health Organization: Monograph Series* No. 9)

Malaria terminology,[24] the work of a drafting committee appointed by WHO, is a guide for malaria workers in that it describes what amount to standardized procedures in epidemiological inquiries on malaria. The terms cover the malaria parasites and the infections to which they give rise, the measurement of malaria in the human community, and the malaria vector. The standardization which this work furthers is of great importance in making possible the assessment of results of malaria-control campaigns and the comparison of results in different countries. A French equivalent of this monograph, *Terminologie du paludisme*,[25] has also been published.

The latest monograph on malaria [in press] is *Chemotherapy of malaria*,[26] an up-to-date review of current knowledge of antimalarials and their place in malaria control. It considers the rationale of malaria chemotherapy from both the chemical and the biological approach, discusses each of the commonly used compounds in detail and the resistance to them which is sometimes manifested, and describes the clinical use of antimalarial drugs.

The *Chronicle of the World Health Organization*, in addition to giving an account of the Organization's activities and summarizing its more technical publications, contains, on occasion, full reports on conferences or on meetings of consultant or study groups. Two meetings of interest to malaria workers were thus reported in the *Chronicle* last year : the First Asian Malaria Conference, and the First International Symposium on the Control of Insect Vectors of Disease.

Papers which are considered of less lasting value than those included in WHO publications are often given limited distribution in the form of mimeographed documents. Such documents are intended mostly for members of expert groups or for internal use by the Organization or institutes with which it works.

A list of publications on malaria may be found on page 97.

TOWARDS WORLD-WIDE ELIMINATION OF MALARIA

THE COSTS OF MALARIA CONTROL

The price of malaria control by residual insecticides is but a fraction of what uncontrolled malaria costs a community in terms of the social and economic consequences of the disease. But, although malaria control represents a profit rather than an economic loss for the country as a whole, this profit is not noted in the record of expenses for the control programme. The expenses are borne largely by the central government, or by local budgets, whereas the profits go for the most part into family budgets. Governments might justifiably recoup their expenses by an increase in taxation, or by charging the communities concerned—and through them the families of the community—for malaria control which has been undertaken, as is done, for example, in Spain. Regardless of the means by which they are financed, however, malaria-control measures would be more readily applied if they were less expensive than they are today.

[24] Covell, G., Russell, P. F. & Swellengrebel, N. H. (1953) *Malaria terminology ; report of a drafting committee appointed by the World Health Organization*, Geneva (*World Health Organization : Monograph Series* No. 13)

[25] Vaucel, M., Roubaud, E. & Galliard, H. (1954) *Terminologie du paludisme ; rapport d'un comité de rédaction nommé par l'Organisation Mondiale de la Santé*, Geneva (*World Health Organization : Monograph Series* No. 25)

[26] Covell, G., Coatney, G. R., Field, J. W. & Singh, J. (1955) *Chemotherapy of malaria*, Geneva (*World Health Organization : Monograph Series* No. 27)

WHO has always given considerable attention to the problem of the costs of malaria control. Among the tasks of demonstration teams is that of experimenting with systems of selective spraying and trying to determine whether or not a single spraying might suffice to control malaria.

It has been found that in some countries a single annual spraying with 2 g of DDT per m^2 can effectively control malaria; yet, in nearby countries where the vectors are the same and climatic conditions similar, two sprayings per year have been adopted. It appears that the periodicity of the spraying operations, as well as selective spraying, needs further exploration, and that an experimental sector should be set aside in every large malaria-control programme for experimenting with different cycles and patterns of spraying. Is it necessary, for example, to spray all the buildings, even those that do not shelter any man or animal? Is it essential everywhere that all inner surfaces of houses be sprayed? Questions such as these are being answered in many countries by experiments undertaken by WHO team members, as has been noted in the descriptions of malaria-control campaigns—for instance, with regard to the " taitoons " in Thailand (page 67), spraying only up to a height of 2 m in Burma (page 53), and a particular type of selective spraying in Taiwan (page 58), in all three of which the vector was *A. minimus*.

If malaria control in Africa south of the Sahara were carried out according to the recommendations of the Kampala conference (see page 81), it is likely that in many areas it would be doomed because the costs would be too great. In all the pilot projects assisted by WHO in Africa, various insecticides, dosages, and patterns of selective spraying are being experimented upon in the hope of finding methods more economical than those recommended at the conference.

As has been previously indicated, costs of spraying operations are carefully noted and analysed in all WHO-aided malaria-control projects. Table I (page 70) shows the costs per person per year of the projects in Asia. It will be seen that these range from US $0.10 to $0.35, excluding Cambodia where, because of unusual conditions, the cost was $0.43. In south-east Asia the maximum was reached in Burma ($0.24), owing to a low population density and a relatively high wage level of personnel employed for the control work.

It is felt that the cost of malaria control should represent only a small proportion of the annual budget for public health. If the latter amounts to the equivalent of US $0.50 per person per year and malaria control costs $0.25, it is doubtful whether malaria control on a nation-wide scale would be possible. It could become conceivable, however, if plans were made to eradicate malaria from the territory within a few years, so that eventually the recurring item of malaria control could be struck from the annual budget. It might also be feasible if, as has been suggested, the government found a way to have its expenses reimbursed by those who profit from malaria control. Finally, there is the possibility that the per person cost of malaria control could be further reduced, making it less of a burden on the public health budget.

RESISTANCE OF ANOPHELINES TO INSECTICIDES

It was in 1947 that the development of DDT resistance in flies was first reported, although this resistance did not become a well-established fact until the following year. The implications for anopheline control were quickly recognized, but it was only in 1951 that the development of resistance to insecticides was observed in certain vector species: *A. quadrimaculatus* in the USA,[1]

[1] Ludvik, G. F., Snow, W. E. & Hawkins, W. B. (1951) *J. nat. Malar. Soc.*, 10, 35

A. sacharovi in Greece,[2] *A. albimanus* in Panama,[3] and, later, *A. superpictus* and *A. maculipennis* in Greece.[4]

The problem of resistance in *A. quadrimaculatus* in the USA is still being discussed. Evidence has accumulated to show, however, that *A. sacharovi* has developed a physiological resistance to DDT, and that, in the case of *A. albimanus*, the resistance is of a behaviouristic type. In some localities in Java, *A. sundaicus* has apparently also developed resistance to DDT; this resistance seems to be physiological in areas where antilarval measures were formerly applied and behaviouristic in others where they were not undertaken (W. J. Stoker—personal communication, 1954).

Many other species have been claimed to have developed DDT resistance, but few, if any, of the reports have been sufficiently substantiated. Some confusion has resulted from a lack of definition of exactly what is meant by resistance to insecticides. At the First International Symposium on the Control of Insect Vectors of Disease (see page 82), the following definition was given : " Resistance to insecticides is the development of an ability in a strain of an insect to tolerate doses of toxicants which would prove harmful to the majority of individuals of a normal population of the same species. The term 'behaviouristic resistance' describes the ability to avoid a dose which would prove harmful."

From this definition it is clear that the term " resistance " alone could be employed only for physiological resistance. It may be inferred that, while behaviouristic resistance need not necessarily interfere with the control of transmission, physiological resistance will, as soon as it has reached a certain level. Physiological resistance of anophelines in Greece, in 1952, did not seem to prevent continued control; but, when the data for the 1953 malaria-control campaign in Greece were obtained, it was recognized (G. Belios & G. A. Livadas—personal communication, 1954) that a high proportion of the malaria cases which had occurred in that year had taken place in villages which had been preventively sprayed with DDT. It then appeared that in these villages DDT had failed to prevent transmission. Similarly, in 1954 a small epidemic of malaria caused by *A. sundaicus* in DDT-sprayed Tandjung Priok and Tjirebon, Java (W. J. Stoker—personal communication, 1954) was another example of how DDT resistance may cause failure in efforts to control malaria.

It has been noted that in the USA *(A. quadrimaculatus)*, in Greece *(A. sacharovi, A. superpictus,* and *A. maculipennis)* and in the above-mentioned localities in Java *(A. sundaicus)* where resistance may have, or has, developed, larvicidal measures have also been applied. This is the reason for the recommendation at the Rome symposium on insect vectors of disease that " the use of chemically related insecticides against both the adults and the larvae of the same species should not be carried out simultaneously in the same area ". It should be mentioned, however, that WHO team members working in Lebanon observed DDT resistance in *A. sacharovi* in two villages in which no deliberate larvicidal measures with chlorinated hydrocarbon insecticides had ever been recorded.[5] It would be difficult to exclude the possibility that contact of the insecticide with the larval population of the vector species had occurred, however, since farmers may have used the insecticide.

It is quite possible that switching over to other chlorinated hydrocarbon insecticides may be successful when signs of resistance

[1] Livadas, G. A. (1951) *Do anophelines acquire resistance to DDT ?* (Unpublished working document WHO/Mal/74)

[2] Trapido, H. (1952) *Amer. J. trop. Med.*, 1, 853
Trapido, H. (1954) *Bull. Wld Hlth Org.*, 11, 885

[4] Livadas, G. A. (1954) *Riv. Malar.*, 33, 23
Belios, G. (1954) *Riv. Malar.*, 33, 33

[5] Garrett-Jones, C. & Gramiccia, G. (1954) *Bull. Wld Hlth Org.*, 11, 865

to DDT appear; DDT resistance does not necessarily imply a polyvalent resistance to all the insecticides of the group. Although *A. sacharovi* in Greece was stated to have become resistant to BHC and to chlordane as well as to DDT,[6] it was still susceptible to dieldrin. But it is likely that once resistance to one of the members of the group has developed, resistance to the others is acquired more quickly, so that after a few years one may envisage the possibility that the local anopheline population might become resistant to all the chlorinated hydrocarbon insecticides. If at that time malaria has not been eliminated from the country and control must be continued, will it be practicable to employ organic phosphorus insecticides, against which, in nature, the development of resistance in insects does not seem to occur so easily? If not, will it be necessary to go back to the pre-DDT era, with space-spraying, or antilarval measures, or to adopt once again that eclectic system which, before the Second World War, was applied in the Pontine Marshes? If so, not much hope would be left of eradicating malaria from many countries in the near future.

Certainly, chemistry may produce powerful synergists of present preparations, or new and better insecticides, less toxic and more lasting than the phosphorus compounds of today. In the meantime, there is encouragement in the observation that the development of resistance seems to require many years of exposure to the insecticide, which means that, by greatest efficiency in malaria-control spraying operations and by covering as large an area as possible, total interruption of malaria transmission might achieve elimination of malaria parasites from the area before resistance to the insecticide has time to develop.

[6] Livadas, G. A. & Georgopoulos, G. D. (1953) *Bull. Wld Hlth Org.*, **8**, 497
Georgopoulos, G. D. (1954) *Bull. Wld Hlth Org.*, **11**, 855

PLANNING FOR THE FUTURE

In the first years of application of residual insecticide spraying, it was thought that this control measure would be a recurring one, like the chlorination of water supplies, and that therefore expenditures for spraying would have to be maintained from year to year. In 1950 the possibility of discontinuing residual spraying was envisaged; and in 1953 the WHO Expert Committee on Malaria concluded that " the practice of discontinuing residual spraying, under proper safeguards, after several years of achieved malaria control, is both logical and feasible, and should be given careful consideration by administrations that have carried out malaria control to a satisfactory end-point in all or the major parts of their territories ".[7] Thus far this interruption of antimalaria spraying operations has taken place, on a larger or smaller scale, in a few countries: British Guiana, Ceylon, Greece, Italy, Thailand, and the USA.

Interruption of residual spraying requires either that the anopheles vector species be eradicated or that no more malaria infectors exist in the area. The first condition does not generally apply and is not the recommended goal of residual spraying, but it has been practically achieved in British Guiana (*A. darlingi*), in some parts of Italy (*A. labranchiae*) and of Greece (*A. sacharovi*), in some sections of Java (*A. sundaicus*), and in certain areas of Thailand (*A. minimus*). More commonly, spraying campaigns succeed in interrupting transmission although the anopheline vector species are still present, resulting in a state of " anophelism without malaria ".

The two main malaria infections of man, when they do not kill, do not last long even if untreated. With few exceptions falciparum infections do not last longer than one year, and vivax infections longer than two years. If no new cases occur in a community for

[7] *Wld Hlth Org. techn. Rep. Ser.*, 1954, **80**, 24

three years, and if no newly infected persons migrate into the community and no member of the latter goes into areas where malaria may be contracted, the community could be considered free of malaria infection, in both man and mosquito. Except perhaps for infections caused by *P. malariae*, generally limited to a few localities, it might be assumed that the hypothetical community above would have achieved eradication of malaria.[8] The danger of a return of transmission would exist only in the importation of infection from outside the community.

If, instead of in an isolated community, malaria eradication were achieved over a very large area—for example, a group of countries or a continent—the dangers of reintroduction of the infection into any of the malaria-free areas would be greatly reduced. The implications are obvious: malaria-control programmes should be planned so as to arrive at eradication simultaneously in as large an area as possible. WHO has discussed this concept at its malaria conferences and has offered its assistance to governments in planning control programmes along these lines within countries and between countries.

Although the general trend in malarious countries today is to extend control measures as much as possible, the ultimate objective of eliminating malaria as a public health problem from the world calls for a revision of strategy, at both the national and the international level.[9] On the national plane, the more malaria is being controlled, the more difficult it will be to ensure credits for the continuation of the work. When control is so successful that only a few cases occur every year, it will become increasingly difficult to guarantee the allocation of funds for maintaining the antimalaria campaign at the same level of efficiency as was achieved when malaria was the cause of much illness and economic loss. There are two alternatives: continuing, year after year, the present campaigns, until the government stops the credits or, perhaps, until the local vectors become resistant to the insecticide, with serious consequences in either case if malaria has not yet been fully eliminated; or concentrating efforts on eliminating malaria within a few years. The latter course is naturally to be preferred, though the immediate costs would be greater. However, it entails a revision of plans so that malaria-control efforts may be co-ordinated, control of selected localities be replaced by area control, and efficiency of operations and their supervision be intensified. At the international level, co-ordination of malaria-control programmes between countries is required.

This new strategy might bring about important changes in the type of assistance given by WHO. The old formula of the demonstration team might become obsolete, but expert advice to governments by individuals or by pilot or advisory teams might be requested more frequently.

Intensifying malaria-control efforts would mean a need for more trained personnel, and this would call for a redefinition of training programmes. In addition, training in special procedures would become essential. The determination of the end-point of malaria transmission requires new techniques, in which very few countries have any experience. Even the most sensitive indicator of transmission, the infant parasite-rate, may not be reliable and may suggest that there is no more transmission when other means of investigation, such as an adequate " epidemiological surveillance ", as it has been termed in Greece, might reveal that transmission is still continuing and needs to be stopped before spraying can be discontinued. To

[8] According to the criteria set forth by the National Malaria Society of the USA, eradication is achieved when no primary indigenous case has occurred in a given area for three years. (See *Wld Hlth Org. techn. Rep. Ser.*, 1954, **80**, 32.)

[9] See Pampana, E. J. (1954) *Bull. Wld Hlth Org.*, **11**, 513 (résumé in *Chron. Wld Hlth Org.*, 1954, **8**, 328).

train personnel in the new techniques of determining the end-point of transmission governments may request WHO aid. They may also seek advice from the Organization on when malaria-control campaigns can safely be interrupted.

There is still another consideration in planning for eradication of malaria. When elimination has actually been achieved and maintained—that is, when spraying has been discontinued and there has been no transmission of the infection for a few years—then precautions must be taken to assure that the disease does not return. This maintenance, or surveillance, should begin not with interruption of spraying, but at least one year before. It would not require a special antimalaria service and might well be part of general rural health services, if these were adequate and if the personnel had first been given the necessary training. Thus the complete integration of the malariologist into the general public health team might be envisaged.

PRESENT OBSTACLES

From what has preceded it may be concluded that, thanks to the effectiveness of modern adulticidal spraying against anophelines, it is not unreasonable to begin planning for world-wide eradication of malaria. At the present time there are no obvious technical or economic reasons why malaria could not be driven out of the Americas, Europe, Australia, and much of Asia within the next quarter of a century. As regards tropical Africa, the situation is not quite so promising, owing to the current relatively high costs of malaria control in that region and to the absence thus far of any convincing success on a country-wide scale. There is no reason to doubt that the difficulties will be overcome, but one cannot yet foresee the elimination of malaria from Africa in the near future. This is true also of several islands of the Pacific and a number of jungle-covered areas of south-east Asia.

The principal obstacles now delaying complete coverage of malarious areas with modern residual spraying are not so much technical or biological or economic as they are social. Among such obstacles are widespread absence of an educated and effective public opinion with regard to malaria elimination in many of the most highly malarious countries, much too limited use of sound administrative principles in the practice of public health, lack of sufficient numbers of specially trained personnel for country-wide malaria-control operations, failure by too many public officials and influential citizens to recognize the economic significance of malaria and its control, and insufficient international co-ordination in planning region-wide malaria-elimination projects. Great progress is evident in dealing with these obstacles, but much remains to be done.

The question of resistance of malaria vectors to organic toxicants, discussed in the previous section (page 90), is also of great importance and must be kept in mind. As has been suggested, it is a reason for pushing control projects forward as widely and as rapidly as possible so that malaria eradication can be attained before such resistance destroys the usefulness of the insecticides.

IMPLICATIONS OF MALARIA ERADICATION

The impact of eradicating malaria from a country will, of course, vary from place to place, depending on the initial degree of malariousness and on existing social conditions. In some areas removal of the burden of malaria will undoubtedly bring about important social and economic changes, including not only a stimulation of agriculture, industry, education, and public welfare generally, but also, in some instances, an immediate increase in population pressure.

FIG. 25. HEALTH EDUCATION IN MALARIA CONTROL

Health education is needed to win public support for malaria control. Here a public health nurse is shown addressing a group of villagers in India, explaining to them the operations which are to be undertaken by a WHO/UNICEF malaria-control team

In Sardinia, the economic and social welfare of the people has already been greatly and quite visibly improved by the elimination of malaria. In British Guiana, malaria control has lowered death-rates so dramatically that it has aroused some pessimistic warnings and has given rise to such statements as " The gadgets of short-term public health can speed the production of festering slums much faster than was possible in the past."

One outstanding writer has posed the question " But is the world the better for having a larger number of healthy people dying of starvation, rather than letting them die of malaria ? " Professor A. V. Hill has pointed out, " It is *not* a question only of food; if a higher standard of life is to become universal, with education, communications, housing, reasonable amenities and public health, a far greater demand will be made on all such natural resources as power, chemicals, minerals, water and wood. One is left wondering how long these can possibly take the strain." [10]

The question of population pressure is not at all as simple as one might think from the comments of some writers. The world population today approaches 2.5 billion,

[10] Hill, A. V. (1952) *Nature (Lond.)*, 170, 388

and it has been predicted that it may reach 4 billion (maximum figure) by the year 2000. Who knows which experts are correct among those who variously estimate that today's knowledge of agriculture should make possible the production of adequate, nutritious food for a world population of 4, 5, or up to 13 billion people ? Who can estimate the effect in the future of greater saving of rainfall, or of the economic utilization of sea water for irrigation; of vastly multiplied "fish-farming"; of widespread, practical photosynthesis; of the production of food from chemicals, woods, and crops that are not edible today ? The equation of population with its three main variables—people, energy, and food—is vastly more complicated than any present formulation.

The answers to the natural query about the possible disastrous demographical effects of malaria control are : first, that no one can have the prescience necessary to justify, because of presumed future good, the present withholding from any people of those methods that are available for the cure and prevention of disease; secondly, that no one knows or can predict exactly what total population the world can adequately support; thirdly, that there is as yet no widespread understanding of the possibilities and benefits of family planning, although in certain overpopulated countries, such as India, the subject is now receiving much attention.

Again quoting Professor Hill, "It is true that scientific research has opened up the possibility of unprecedented good, or unlimited harm, for mankind; but the use that is made of it depends in the end on the moral judgments of the whole community of men. It is totally impossible now to reverse the process of discovery : it will certainly go on. To help to guide its use aright is not a scientific dilemma, but the honourable and compelling duty of a good citizen."

Malaria eradication is certainly not an end in itself. Malariologists, physicians, and sanitarians should, to an ever greater extent, integrate their activities into those of agriculturists, industrialists, social scientists, economists, educators, and political and religious leaders. But it has been repeatedly demonstrated that, in highly malarious countries, one of the first steps in the improvement of public welfare is the removal of malaria, which, like a blanket, stifles all aspects of human endeavour.

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MALARIA TERMINOLOGY

Report of a Drafting Committee Appointed by the World Health Organization

Sir Gordon COVELL,
P. F. RUSSELL &
N. H. SWELLENGREBEL

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